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ANALYSIS OF COMMERCIAL EQUIPMENT AND INSTRUMENTATION FOR SPACELAB PAYLOADS

(CONTRACT NAS8-30541)

VOLUME III. DESIGN ANALYSIS AND TRADE STUDIES

SEPTEMBER 16, 1974

Approved: R.P. Arras

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Study Manager

Space Division
Rockwell International

FOREWORD

The Analysis of Commercial Equipment and Instrumentation for Spacelab Payloads was performed by the Space Division of Rockwell International Corporation under Contract NAS8-30541 for the George C. Marshall Space Flight Center of the National Aeronautics and Space Administration. The study explores the feasibility of using commercially available laboratory equipment and instrumentation in the Spacelab, a Shuttle payload, in support of various sortie-mode experiments. The work was managed by Richard P. Arras (Telephone (213) 594-3807) of the Applications Programs area of the Space Division of Rockwell International. The study was administered under the technical direction of Mr. Charles W. Quantock (Telephone (205) 453-3425) of the Payload Studies group of Program Development of the Marshall Space Flight Center.

ACKNOWLEDGEMENTS

The continuing guidance and support given by the Contracting Officer's representative, Mr. C. W. Quantock of MSFC, is gratefully acknowledged. In addition, acknowledgement is made to Messrs. J. Hendrick, P. Fagan, P. Hinderer, E. Kraly, T. Meinhardt, M. Pope and E. Tivenan of Rockwell International, and G. Bordeaux, J. Hammond, and C. Stata of Beckman Instruments for their technical assistance. Without their technical support and the cooperation of many commercial equipment manufacturers this study could not have been accomplished. Finally, the study manager wishes to acknowledge Ms. L. Aldrich and Ms. C. Perry who typed all the material in these volumes.

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1.0 INTRODUCTION

Volume III has been organized to supplement the information presented in Volume II. Detailed information is presented which was used to make the conclusions discussed in Volume II. General data used to support more than one activity are also included in this volume.

Section 2.0 presents the detailed analysis of each selected equipment item. Suitability and cost analyses have been documented by equipment item.

Tradeoffs of alternative specification requirements are presented in Section 3.0. The tradeoffs discussed include possible relaxation of vibration, material control, fungus and corrosion requirements for experiment equipment. An additional tradeoff was performed to determine whether it is cost effective to modify experiment equipment to be compatible with a 28-volt dc power source rather than the conventional 110-volt ac source.

Section 4.0 presents the programmatic analysis data that were used as the basis for the extension of results from the analyses of specific equipment items to the entire Spacelab experiment program.

2.0 SELECTED EQUIPMENT ANALYSES

This section presents the suitability and cost analyses of available equipment on an item-by-item basis. Each section is similarly organized.

The first three subsections describe the unit analyzed. Following a title page which includes a picture of the unit, its manufacturer, model number and cost, a narrative explains how the unit functions. Next, the performance and physical characteristics for the item are tabulated. Performance characteristics shown include most functional performance specifications defined by the manufacturer for the unit. In some cases, published specifications were so extensive that editing of detailed specifications was required. However, in all cases, the primary performance characteristics are reported. Physical characteristics include weight and size of the package(s) analyzed.

The analysis of the selected hardware items relative to the Spacelab/Experiment Equipment Interface Requirements (SEEIR) specification (Appendix D, Volume II) is presented in the next three subsections. This information provides the basis for Section 3.0 of Volume II. Equipment characteristics requiring modification are identified by the suitability analysis of each item. Photographs of these characteristics are included to illustrate construction practices used by the equipment manufacturers. Conceptual definition of each modification is presented in the following subsection. Cost estimates for the modified hardware and custom building the same hardware follow this subsection. Retail costs shown in these sections have been adjusted for material procurement and general and administrative costs incurred by the purchase of the equipment.

The next two subsections itemize the impact of imposing the preliminary equipment specification generated by NASA (Appendix E, Volume II) upon the previously modified hardware. Subsection 7 defines additional modifications made to each item resulting from the delta requirements imposed by the NASA specification in excess to the requirements of the SEEIR. Estimates of the costs incurred by these modifications and additional engineering activities required by the specification are presented in the next subsection. The information from these subsections provides the basis for the discussion in Section 4.2 of Volume II.

The final subsection of each unit's section documents the information sources utilized during the equipment analyses.

2.1 BLOOD CELL COUNTER

Manufacturer: Coulter Electronics
Model Number: F_N
Cost: $5000

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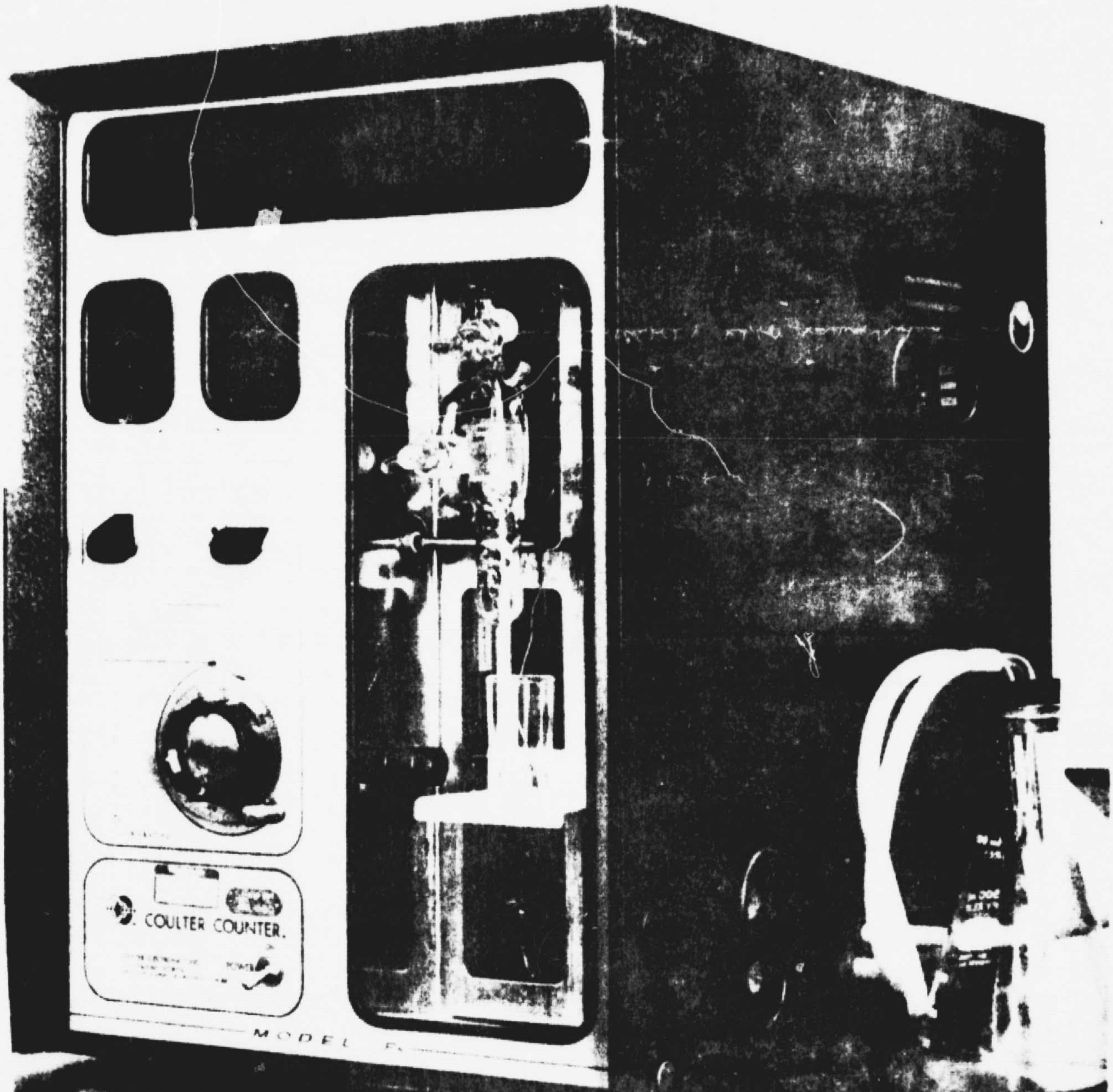

Figure 2.1-1. Coulter Blood Cell Counter

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2.1.1 Description

Particles or cells suspended in an electrolyte are sized and counted by passing them through an orifice (aperture) with a specific flow for a given length of time. The flow is between electrodes permit electronic counting.

As particles or cells pass through the aperture and displace an equal volume of electrolyte, the resistance in the path of current changes. The quantity (magnitude) of this change is directly proportional to the volumetric size of the particle or cell.

The number of changes within a specific length of time is proportional to the number of particles or cells within the suspension.

The Model F_N consists of two units, the Sample Stand and the Electronic Counter, i.. one consolidated cabinet.

Sample Stand. The Sample Stand Assembly (Figure 2.1-2) is located on the right side of the instrument, and is separated into two sections (front and rear) by a metal wall. The front section contains the following:

1. Beaker platform
2. Aperture tube
3. Control piece assembly (contains control stopcock and auxiliary inlet stopcock)
4. Projection lamp assembly (front)

The right side of the cabinet is provided with a door for access to the rear section of the Sample Stand. The rear section contains the following:

1. Beaker platform (rear portion)
2. Control piece assembly (rear portion)
3. Dual volume manometer
4. Projection lamp assembly
5. Vacuum pump

Electronic Counter. The Electronic Counter consists primarily of the front panel which contains:

1. Numeric readout
2. Electronic oscilloscope display
3. Micro projection system

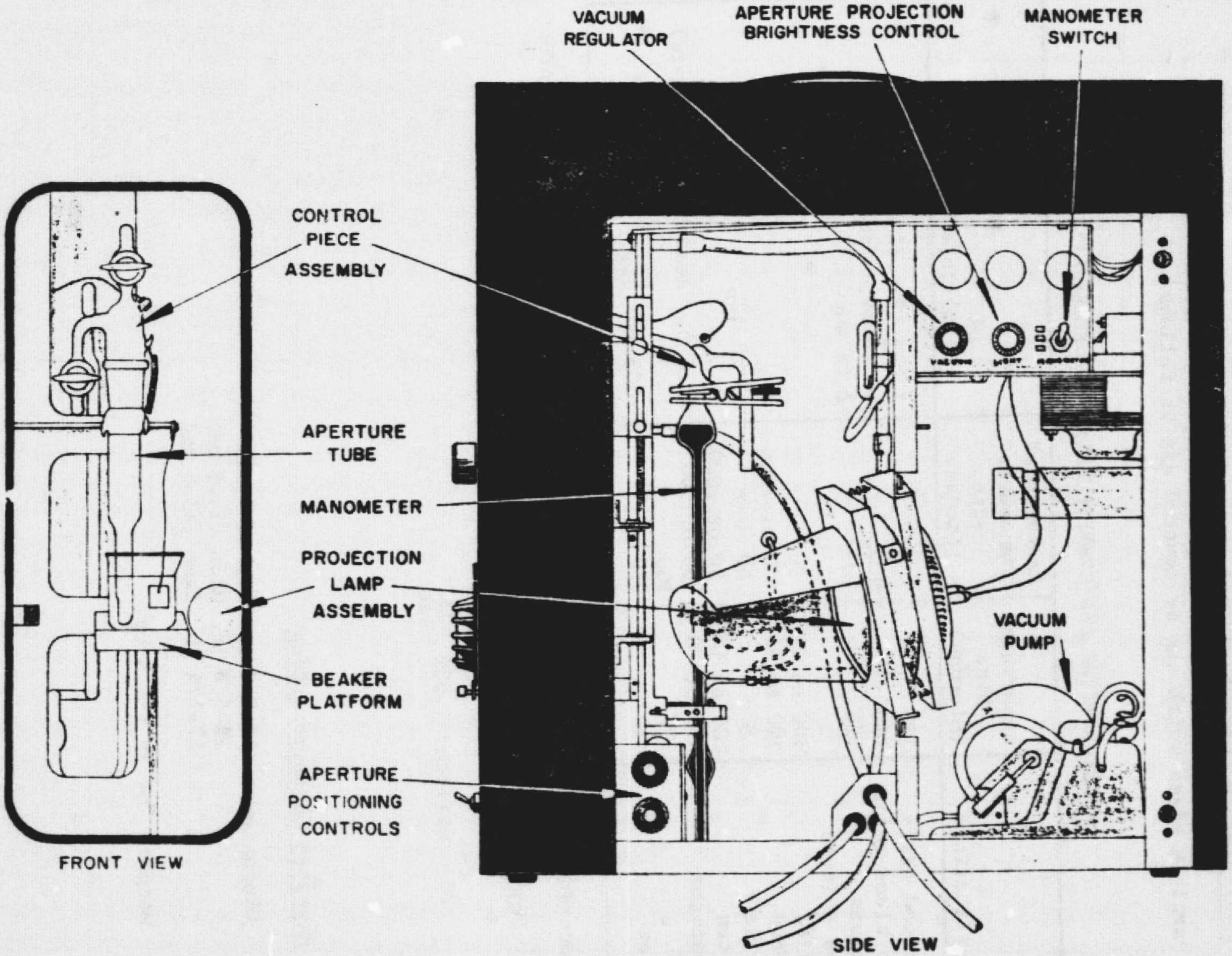

Figure 2.1-2. Sample Stand

2.1.2 Performance Characteristics

Particle sizes which can be counted are as follows:

APERTURE TUBE AND CORRESPONDING MANOMETER SIZES

Applications	Aperture Size (Microns)	Recommended Manometer Size (Lamdas)	Particle Diameter
Red blood cells	100	500	7.5 ± .3μ (2 μ thick)
White blood cells	100	500	10 to 24μ (variable)
Platelets	70	100	2 to 4μ
Tissue culture cells	100 or 200	500	
Protozoa	100 or 200	500 or 2000	
Bacteria	30	50	.3 to 13μ
Plankton	100 or 140	50 or 2000	
Spermatozoa	50 or 70	50 or 500	4 to 5μ (head of human sperm)
Algae	100	500	
Viruses	10	50	.003 to .05μ

Counting rates measured on the Coulter Counter Model F_N at Beckman ATO.

100 orifice: .040 $\frac{m\ell}{sec}$

70 orifice: .022 $\frac{m\ell}{sec}$

2.1.3 Physical Characteristics

Dimensions: 19-3/8 in. high (49 cm)
12-5/8 in. wide (34.6 cm)
17-1/4 in. deep (43.6 cm)

Weight: 54 lb (24.5 kg)

2.1.4 Suitability Analysis

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. Unit is a flimsily constructed laboratory test instrument containing a large amount of glass. Rubber tubes connect many of the glass tubes. The light source is a headlight mounted on thin sheet metal slides (Figure 2.1-3). A large printed circuit board is mounted on top of the unit and a power supply circuit board on the rear vertical (Figure 2.1-4). A cathode ray tube is mounted on one side of the unit.			
MATERIALS. Glass Mercury Neoprene tubing Fiberglass printed circuit boards Plastic knobs PVC insulated wire Glass nixie tubes Foam (undefined material)			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT. The unit is not built to withstand the rigorous environment of the Spacelab. Unit requires complete repackaging and replacement of glass materials. Large electrical components such as capacitors and a transformer are cantilever-mounted on the rear wall of the unit (Figure 2.1-3). The printed circuit board is large and will oil-can in vibration. Large lead-mounted capacitors could break loose (Figure 2.1-4).			X
ELECTRICAL POWER. The equipment is designed to operate at 90 to 135 volts ac, 50 or 60 Hz. Provisions are made for conversion to 180 to 270 volts ac, 50 or 60 Hz, if necessary.	X		
DATA MANAGEMENT COMPATIBILITY. 0.5 v output available.			X
EMI SUSCEPTIBILITY AND RADIATION. Unit has minimal protection. (The removable metal cover is held by two quick-release fasteners.) The CRT sweep and high voltage could radiate interference.			X
FLAMMABILITY.			
Plastics - PVC			X
Exposed electrical insulation (possibly PVC)			X
Foam			X

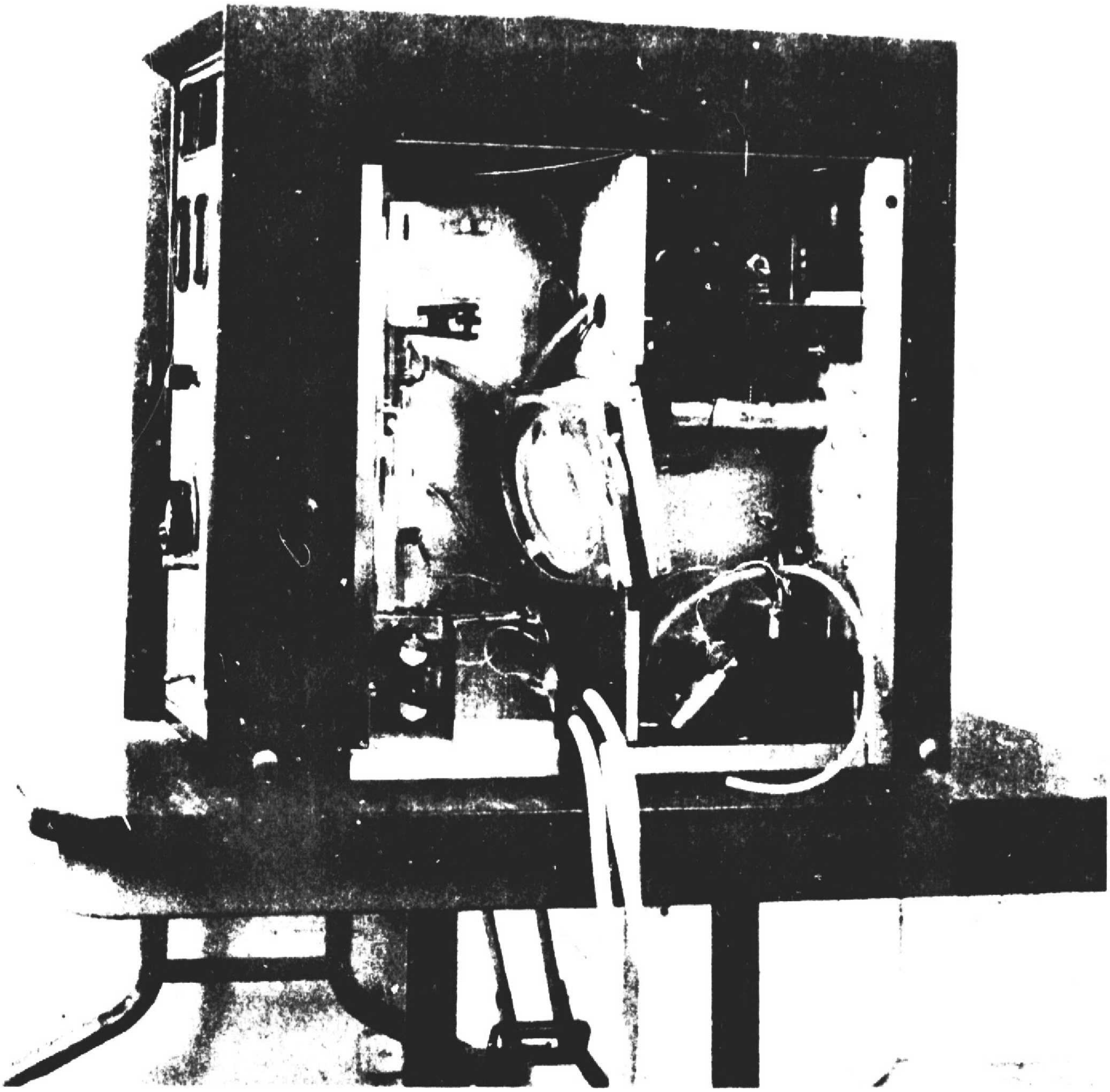

Figure 2.1-3. Side View of Coulter Counter

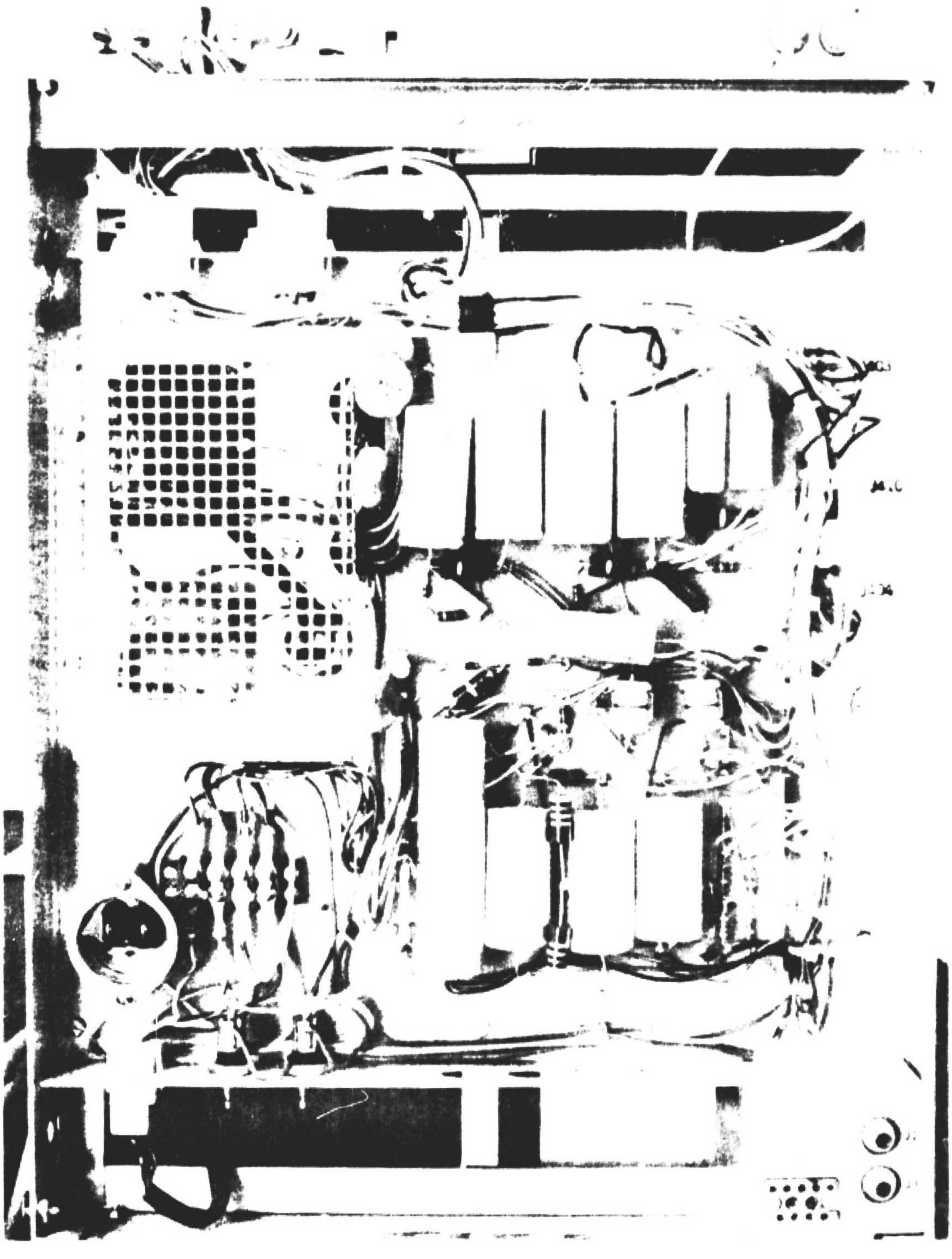

Figure 2.1-4. Lead-Mounted Capacitors

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	Disposition		
	Accept	Verify	Unaccept
TOXICITY.			
Mercury in manometer (Figure 2.1-5)			X
Mercury gas in nixie tubes			X
Neoprene tubing			X
CONTAMINATION GENERATION. High potential for glass breakage and resulting particulate contamination.			X
Organics and entrapment potential for outgassing.		X	
CONTAMINATION SUSCEPTIBILITY. Orifice becomes easily clogged.		X	
ATMOSPHERE. 10 to 90 percent relative humidity; no apparent pressure-sensitive components.	X		
AMBIENT TEMPERATURES. Appears compatible with Spacelab environment.	X		
EQUIPMENT COOLING. Unit relies on natural convection for cooling. Some components have over-heated as a result of inadequate cooling (Figure 2.1-6).			X
ZERO-G EFFECTS. Negative pressure to induce sample flow caused by falling mercury column.			X
Sample is extracted from open beaker.			X
OPERABILITY.			
No protrusion protection.			X
Loose accessories (waste and sample beakers)			X

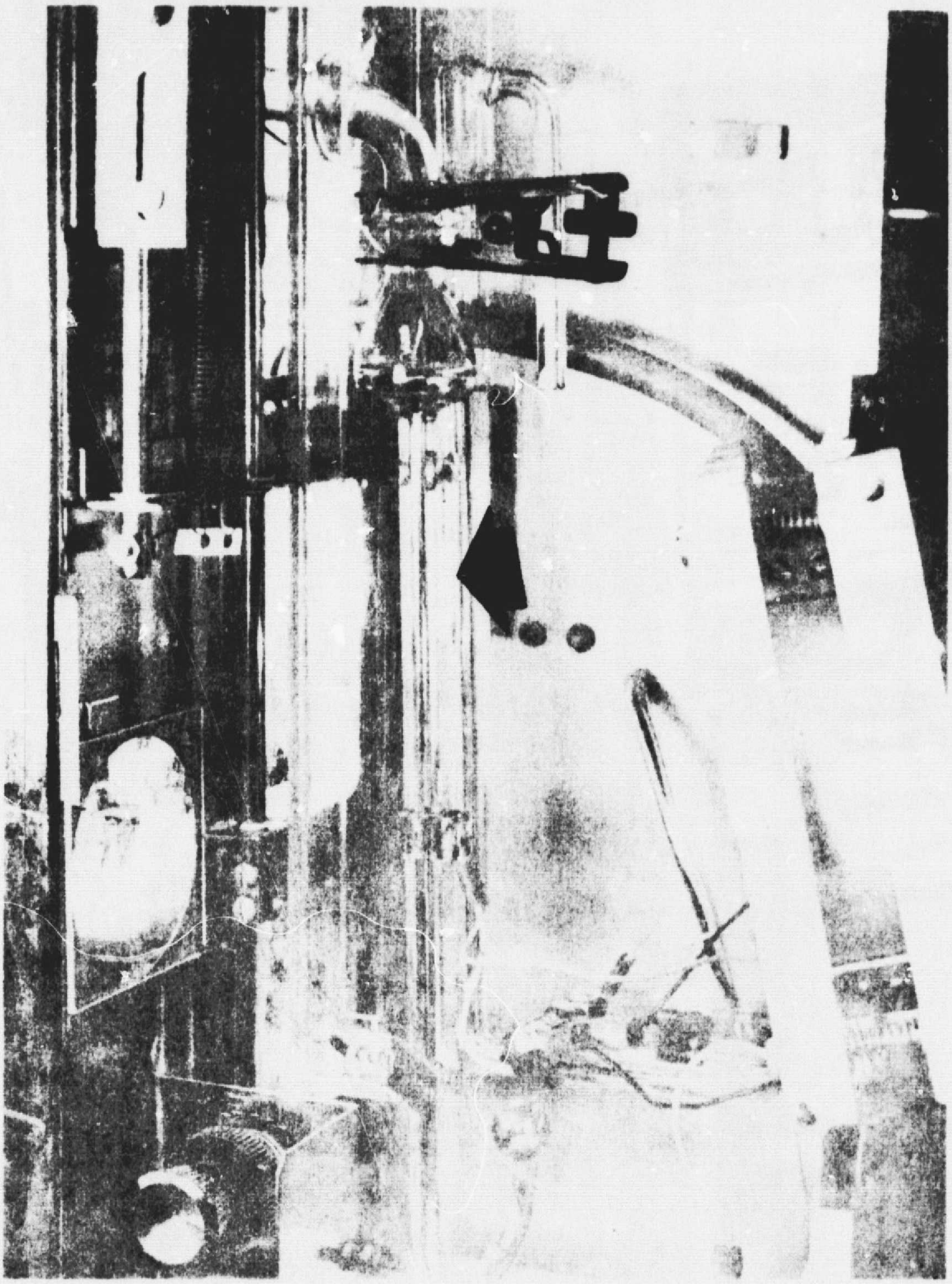

Figure 2.1-5. Mercury Manometer

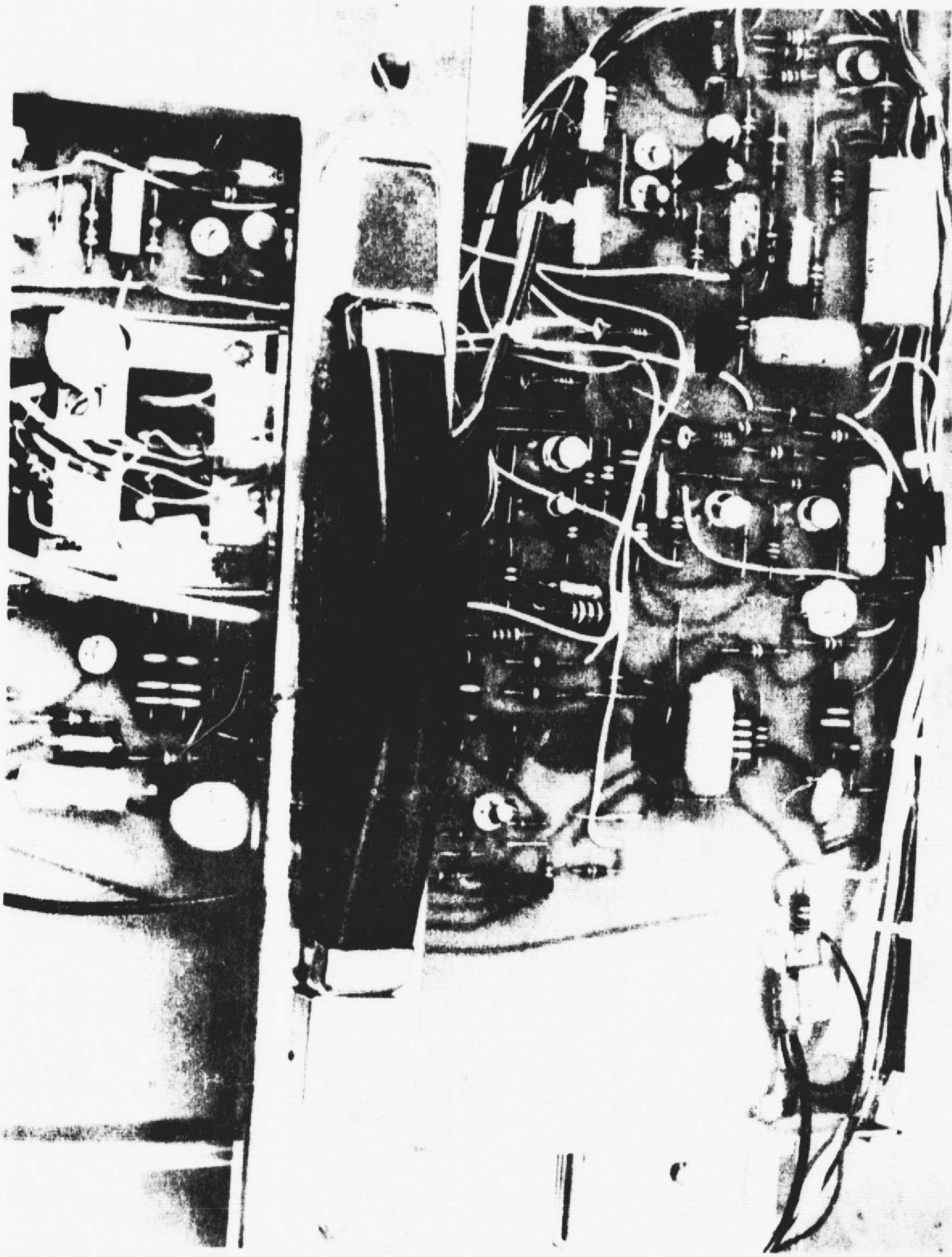

Figure 2.1-6. Over-Heated Electrical Components

2.1.5 Modifications

It was concluded that modification of this unit for operation in the Spacelab would not be cost effective. This unit requires repackaging and replacement of most parts because they are either hazardous or would not survive the boost environment. A new approach to sample flow control must also be developed since the existing unit uses a toxic material, mercury, and relies on gravity to cause the mercury column to fall. Since accurate flow control is necessary to proper operation of the unit, solution to this problem will require considerable development. In reviewing the modifications required for a suitable unit, it is apparent that the revised unit would be completely custom built. Therefore, revised designs and the modification costs have not been determined. Custom-cost data are presented.

2.1.6 Cost Analysis

Modification - Not Applicable

New Development

Cost. $417,000
Weight . . . . 15 lb
Complexity 2.00
State-Of-The-Art Factor 4
Data Source . . . . Beckman Instrument Blood Cell Counter

2.1.7 EC006M Delta Modifications Requirements Summary

Delta modifications due to the EC006M00000A specification were not developed inasmuch as it was determined that modification was meaningless for this unit, as explained in 2.1.5 above.

2.1.8 Data Sources

1. Visual examination of unit
2. Operating Manual - Coulter Blood Cell Counter, Model F_N, Coulter Electronics, Incorporated

2.2 CENTRIFUGRE

Manufacturer:	Clay-Adams, Inc.
Model:	1004
Cost:	$324

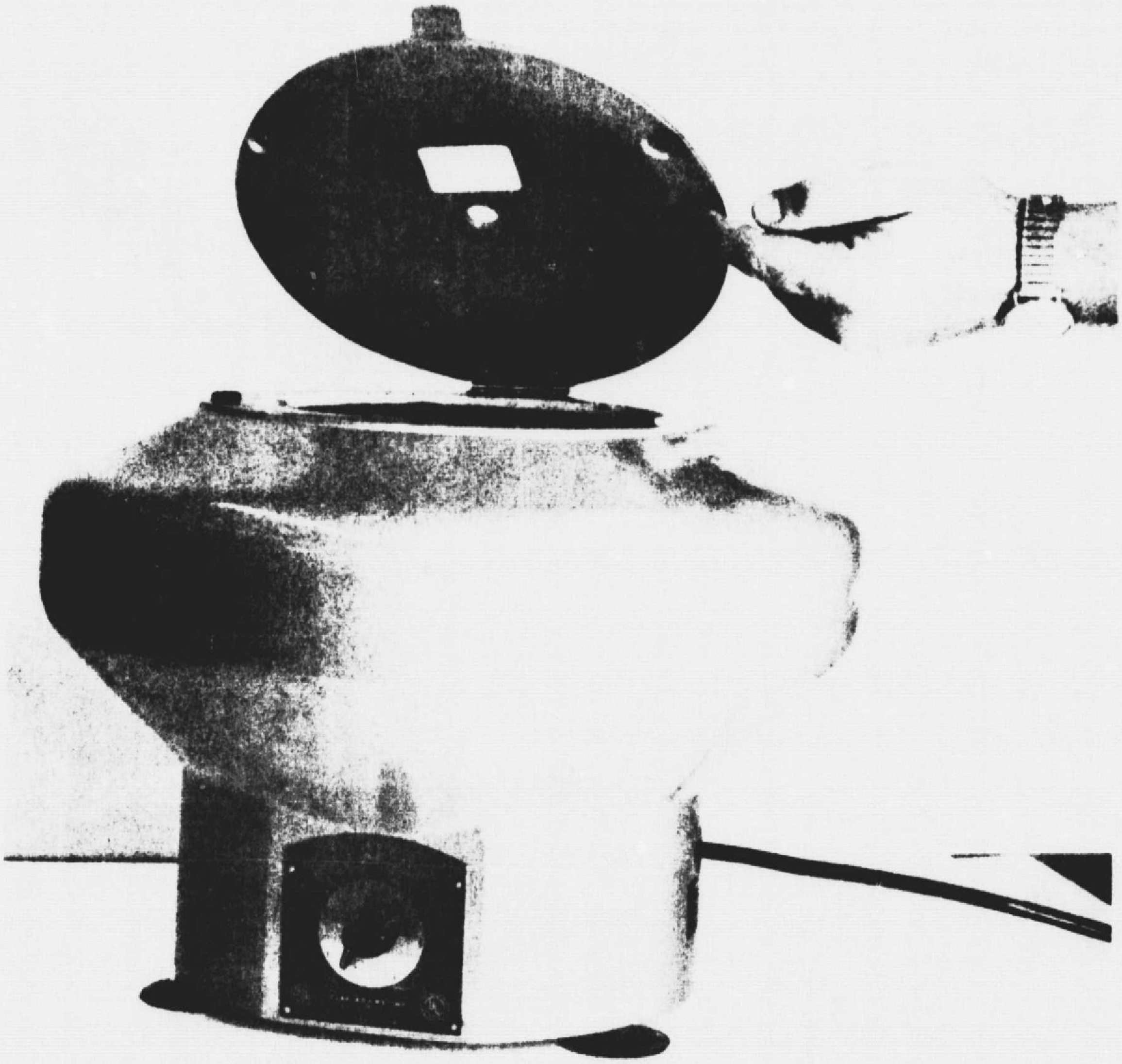

Figure 2.2-1. Clay-Adams Centrifuge

2.2.1 Description

This unit is a typical, low-speed, bench-mounted centrifuge found in many laboratories. It accommodates up to 12 samples. Different tube sizes can be accommodated through the use of various thickness inserts.

2.2.2 Performance Characteristics

Speed range:	800 to 3040 rpm (95 to 1300 rcf)
Maximum number of samples:	12
Maximum sample quantity:	15 ML
Head angle:	52 degrees

2.2.3 Physical Characteristics

Housing Diameter:	15 in. (38 cm)
Height:	12 in. (25.4 cm)
Weight:	26 lb (11.8 kg)

2.2.4 Suitability Analysis

	Disposition: Accept	Verify	Unaccept
CONSTRUCTION. Housing is a one piece, heavy-gauge aluminum casting. The cover seats on unit by gravity. The head has stainless steel inserts with cork cushions at the bottom. This unit is designed for beach mounting, resting on rubber suction cups. The head mounts directly on the motor shaft, motor being located in a lower compartment with the speed control rheostat.			
MATERIALS.			
Aluminum Stainless steel Fabric wire insulation Motor lubricant Rubber cushion and feet Plastic rheostat knob Fishpaper motor insulator			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT.			
Rugged construction	X		
Lid not positively latched			X
Rotor shaft retaining screw not positively locked			X
Rheostat knob needs positive containment on shaft			X
NOISE GENERATION. Approximately 70 to 80 dB. Intermittent operation of unit justifies waver on noise.		X	
FLAMMABILITY.			
Fabric and rubber wire insulation			X
Plastic rheostat knob			X
(Compartment can be sealed by simple modification if desired)	(X)		
TOXICITY. No prohibited toxics or large quantities of potential toxic generators.	X		
CONTAMINATION GENERATION.			
Cast aluminum with chemical-resistant paint; no visual evidence of flaking and peeling	X		
Outgassing possible from motor, entrapments		X	
ELECTRICAL POWER.			
115 vac, 60 Hz, rated at 2 amps max. Power dissipation, 105 watts	X		

	Disposition		
	Accept	Verify	Unaccept
EMI SUSCEPTIBILITY AND RADIATION.			
AC motor can cause conducted power line transients			X
Aluminum housing shields environment from radiated EMI. See Figure 2.2-2.		X	
Power cord not a twisted, shielded type			X
ATMOSPHERE. Not sensitive.	X		
AMBIENT TEMPERATURE. Not sensitive	X		
EQUIPMENT COOLING. The motor will cause enough convection for proper cooling.	X		
ZERO-G EFFECTS. Rotor cover required to retain sample containers and stainless steel inserts in rotor head when centrifuge not operating. See Figure 2.2-3.			X

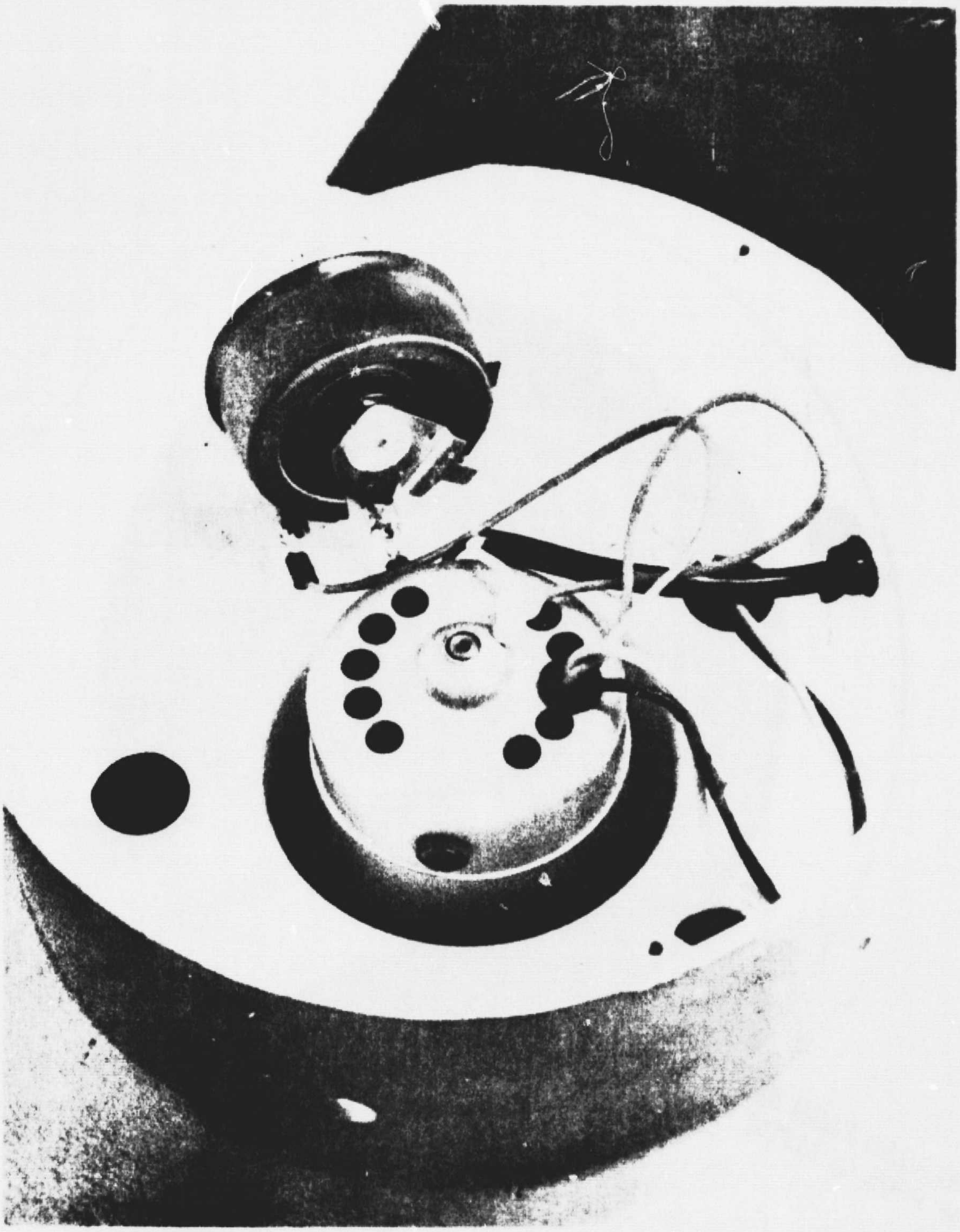

Figure 2.2-2. Centrifuge Motor Installation

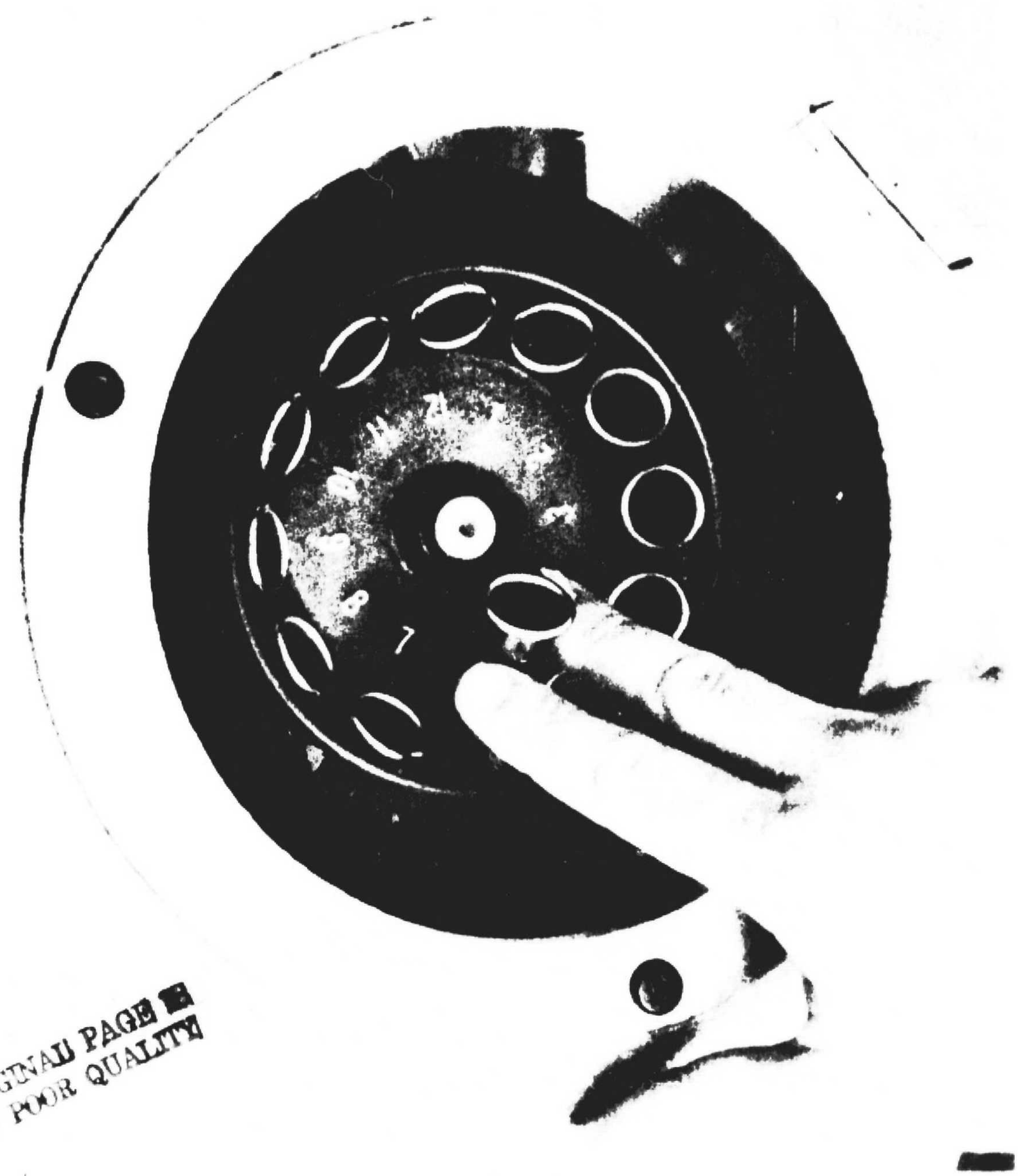

Figure 2.2-3. Centrifuge Head Showing Stainless Steel Inserts

2.2.5 Modifications

Construction

Protrusions. Lip on cover to be removed. See Figure 2.2-4.

Shock, Vibration, and Acceleration

1. Cast-aluminum cover - Added adjustable pawl panel fastener (see Figure 2.2-4).

2. Housing hold-down - Discard existing bottom plate and the four mounting feet. Assembly per Figure 2.2-5.

3. Rocor - Tap motor shaft, 10 to 24 threads, 50 min. Discard existing retaining screw and use new item. See Figure 2.2-6.

4. Wiring - Wiring needs to be held securely with cable clamps. At least two are required.

5. Pin speed control knob to shaft.

EMI Generation Suppression. Line filter required.

Materials

Flaking and Peeling Resistance. Provide 150-hour bakeout.

Concentration of Flammable/Unidentified Materials. Fishpaper insulator under motor to be replaced with a TFE gasket. Wires to be sleeved with heat-shrinkable TFE insulation.

Zero-G Compatibility

Fabricate sample retainment cover as shown in Figure 2.2-7.

2.2.6 Cost Analysis

Modification

Basic Cost		$ 372
Modification Cost		
Fabrication	$1014	
Engineering	3956	
Test	1472	
Documentation	2160	
Program management	391	
Total modification cost		$8993
Total cost		$ 9365

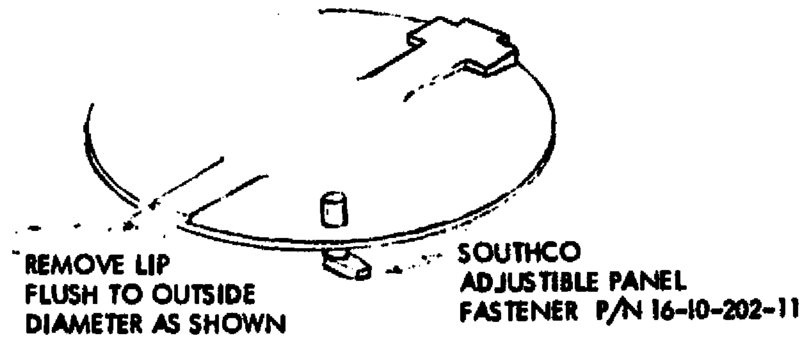

Figure 2.2-4. Modified Centrifuge Cover

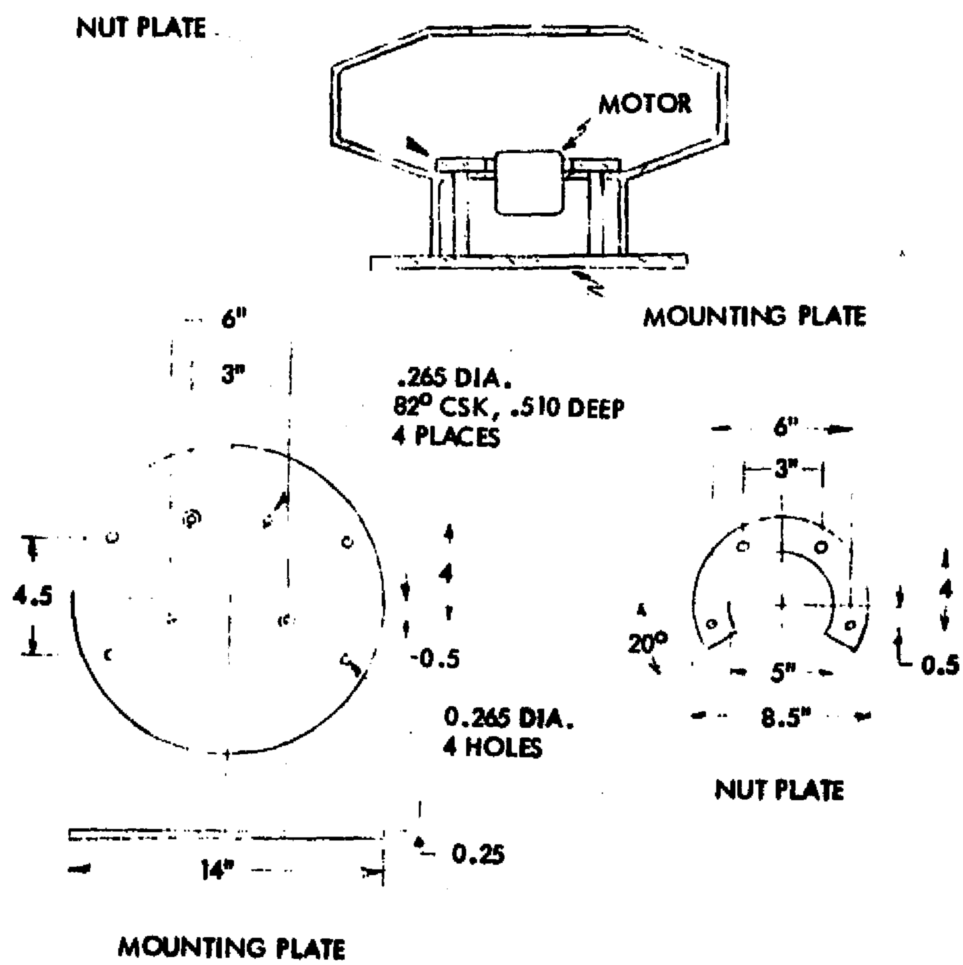

Figure 2.2-5. Housing Hold-Down

Figure 2.2-4. Modified Centrifuge Cover

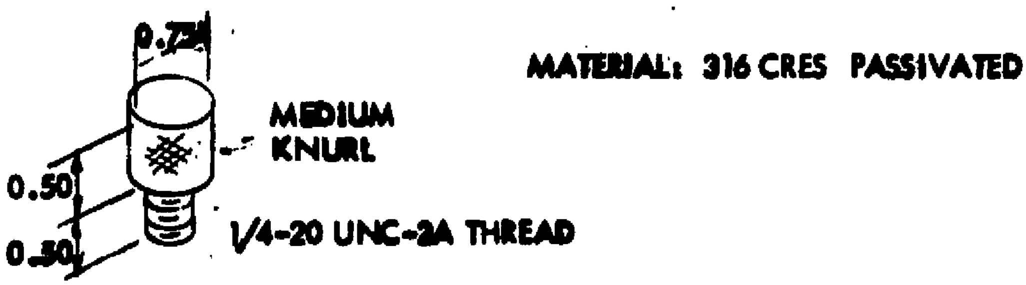

Figure 2.2-6. Motor Shaft Retaining Screw

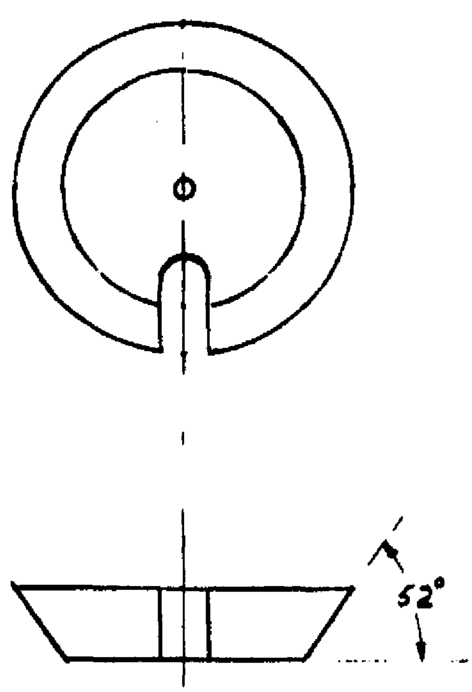

Figure 2.2-7. Sample Retainment Cover

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME CENTRIFUGE NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH.	EXPD.			COST $: MAT'L	LABOR	TOTAL
		Adjustable Pawl		.50		.20			.50				3.00		
		and Remove Lip													
		Mounting Plates		1.00		.20			1.00				7.00		
		Rotor Shaft Mod.		1.00		.20			.50				1.00		
		Install Cable Clamps							.50				.70		
		Install Protective Screens		1.00		.20			1.00				5.00		
		Install Line Filter				.10			.50				12.00		
		Install TFE Gasket													
		& TFE Insulation				.10			.50				5.00		
		System Support & Expedite				1.00	1.00	2.00		1.00					
		& Test													
		150 Hour Bake						16.00					500.00		
		Pin Control Knob to Shaft		.15		.05							.25		
		TOTAL HOURS		3.65		2.05	1.00	18.00	4.50	1.00			533.95		

LOT SIZE FROM	LOT SIZE TO	RATE	MAT'L	LABOR	TOTAL
		O.H.			
		TOTAL	533.95	479.74	1013.68
		TOTAL			
		TOTAL			

Beckman INSTRUMENTS

SHEET 1 OF 1 BY STATA

Space Division
Rockwell International

New Development

Cost	$24,000
Weight	25 pounds
Complexity	0.2
State-of-the-art factor. .	3
Data source.	Space Station Exp. 5.13C

2.2.7 EC006M Delta Modifications Requirements Summary

1. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

2. Human factors modifications are as follows:

   a. Replace lid hinge with a friction hinge.

   b. Add silk-screened operating instructions near control (1).

2.2.8 Delta Modification Costs

Fabrication		
Engineering	$ 7,544	
Test	4,420	
Documentation	2,562	
Program Management	800	
Total delta modification cost		$ 15,362

2.2.9 Data Sources

1. Visual examination

2. VWR Scientific Catalog, 197]

2.3 COMPUTER

MANUFACTURER: DIGITAL EQUIPMENT CORPORATION

MODEL NO.: PDP-8/E

COST: $12,000 (16 K MEMORY)
$22,000 (32 K MEMORY)

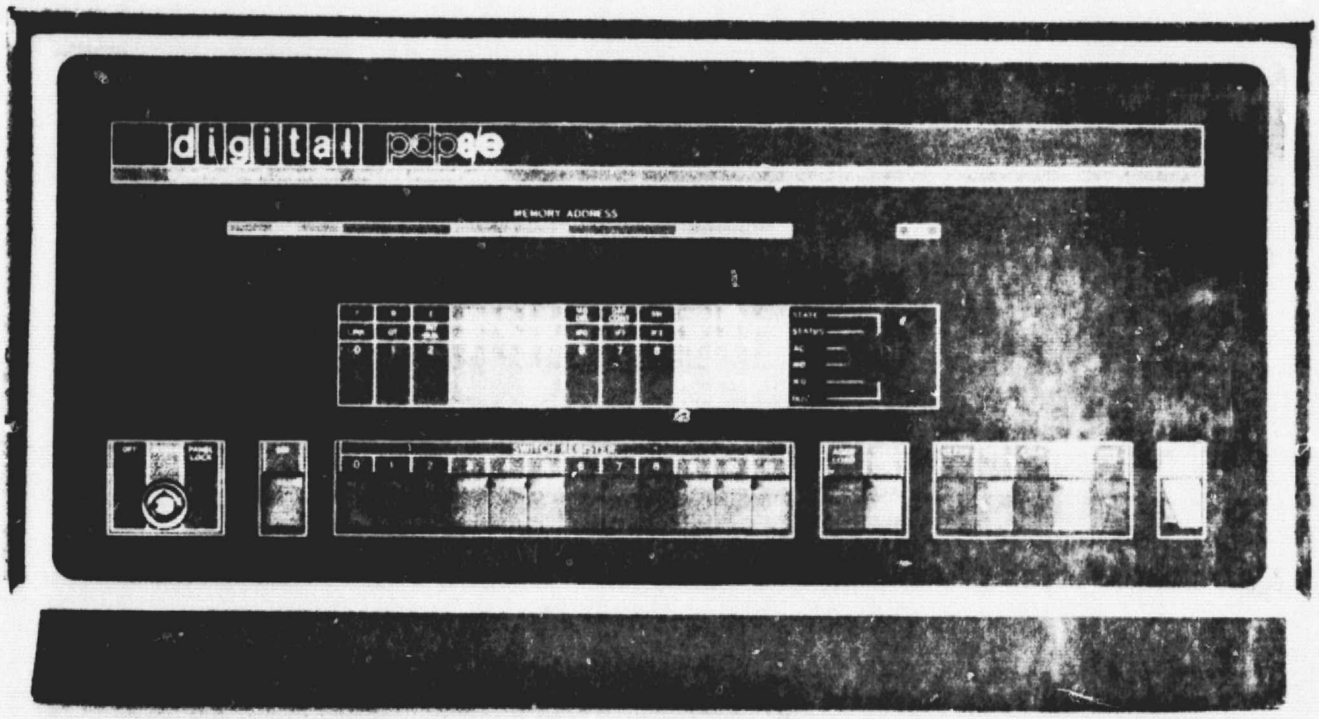

Figure 2.3-1. Digital Equipment PDP-8/E Computer

2.3.1 Description

The PDP-8/E is specially designed as a general-purpose computer. The PDP-8/E basic processor is a single-address, fixed word length, parallel transfer computer using 12-bit, two's complement arithmetic. The cycle time of the random access memory is 1.2 microseconds for fetch and defer cycles without autoindexing, and 1.4 microseconds for all other cycles. Standard features include indirect addressing and facilities for instruction and skipping and program interrupts as a function of input/output device conditions.

Five 12-bit registers are used to control computer operations, address memory, perform arithmetic or logical operations and store data. The PDP-8/E may be programmed manually, using the programmer's console, or remotely, by means of a console terminal.

2.3.2 Performance Characteristics

TYPE:	Single address, fixed word length, parallel transfer programmed data processor
WORD LENGTH:	12 bits
CYCLE TIME:	1.2 or 1.4 microseconds
MEMORY CAPACITY:	4096 or 8192 words, expandable to 32K 8 autoindex registers per 4K memory field
STORAGE MODE:	Two's complement numbers, 6-bit or ASCII characters
ADDRESSING CAPABILITY:	Typically, one instruction may address 256 locations directly or 4096 locations indirectly
INSTRUCTION SET:	6 memory reference instructions, 20 microprogrammable operate microinstructions, and 8 input/output transfer instructions for the CPU and each of up to 63 I/O devices
INSTRUCTION EXECUTION TIME:	Operate microinstruction 1.2 microseconds Directly addressed MRI 2.6 microseconds Indirectly addressed MRI 3.8 microseconds Autoindexed MRI 4.0 microseconds or less
INPUT/OUTPUT CAPABILITY:	Programmed data transfer, program interrupt system transfer, and 13 channels of internal and/or external direct memory access (data break)

2.3.3 Physical Characteristics

SIZE AND WEIGHT:	Typically 19 x 10.5 x 24 inches (48 x 26 x 61 centimeters) at about 95 pounds (43 kilograms)

2.3.4 Suitability Analysis

CONSTRUCTION. The unit is a table-top module with a plastic front face. Fans and high-powered components are located along one side. Printed circuit boards are arranged in a row from front to back with their edges facing the high-power component section. The unit can be obtained in rack mount configuration. However, weight requires pin-mount rack design.

MATERIALS

Panel knobs and fairing
PVC wire insulation
Plastic on each circuit board
Typical electronic components

SHOCK, VIBRATION, ACCELERATION AND ACOUSTIC ENVIRONMENT

	Disposition: Accept	Verify	Unaccept
Shock: 30 g vertical	X		
16 g panel-up drop test	X		
Vibration:			
Spec - Vibrated at 70 Hz during operation to detect poor connections			X
Visual examination - Circuit board installation inadequate (Figure 2.3-2)			X

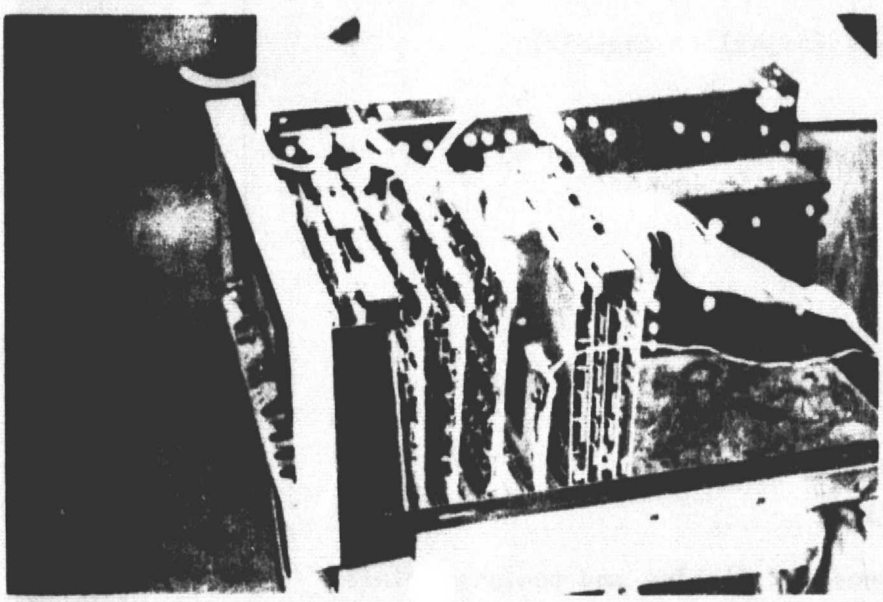

Figure 2.3-2. PDP-8/E Circuit Board Installation

	Disposition		
	Accept	Verify	Unaccept
ELECTRICAL POWER			
95 to 130 v, 47 to 63 Hz, approximately 6 ampere, single phase	X		
Dissipation: 450 w		X	
DATA MANAGEMENT COMPATIBILITY			
External connectors are printed pin PCB connectors instead of pin-type interface connectors			X
5-volt logic	X		
EMI SUSCEPTIBILITY AND RADIATION			
Little shielding used; has metal case and enclosure for electronics/fans on one side		X	
Guard module circuit board to make the unit immune to EMI	X		
Isolated grounds (signal to chassis)	X		
NOISE GENERATION			
Fan noise high; estimated to exceed 60 dB			X
FLAMMABILITY			
Plastics			X
TOXICITY			
No prohibited toxics or large quantities of potential toxic generators	X		
CONTAMINATION GENERATION			
PVC ribbon cabling			X
Plastic knobs			X
No visual evidence of flaking and peeling paints	X		

	Disposition: Accept	Disposition: Verify	Disposition: Unaccept
ATMOSPHERE			
Relative humidity: 10 percent to 90 percent (noncondensing)	X		
AMBIENT TEMPERATURES			
Ambient temperatures: 32 deg to 130 deg Fahrenheit; 0 deg to 55 deg Centigrade	X		
EQUIPMENT COOLING			
Heat dissipation is 1700 Btu/hr. The computer has two internal fans for cooling.	X		
ZERO-G EFFECTS			
No orientation constraints	X		
OPERABILITY			
Dense panel switch grouping		X	
No protrusion protection			X

2.3.5 Modifications

9-G MOUNTING. Wires and cables will have to be clamped. Approximately 10 printed circuit boards have to be conformally coated and retained in their respective slots.

PROTRUSIONS AND EDGES SAFETY. 0.5 R bezel will have to be designed to replace existing bezel. This will be required for edge safety as well as to protect the control switches.

19-INCH RACK MOUNT. Provide pin-type rack support per paragraph 10 of Design Guidelines.

SHOCK-VIBRATION-ACCELERATION. Construct vibration support for 10 printed circuit boards (Figure 2.3-3). Pin knobs to their shafts/levers. Replace 100 fasteners with CRES Nylock type.

FLAKING AND PEELING. Paint and silk-screen front panel are of unknown substance; repaint outside all surfaces with clear, approved paint.

CONCENTRATION OF FLAMMABLE/UNIDENTIFIED MATERIALS. Conformally coat 10 PCB boards.

NON-PREVELANT COMMERCIAL MATERIAL. Replace knobs with metal (front panel switches). Substitute TFE wire to the insulator including backplane wire. Card guides and retracting knobs are unknown. All fasteners will be changed with stainless steel. All cadmium-plated (exposed) parts will be stripped. Bake out 150 hours to expel volatiles.

NOISE. Replace fans with lower speed, lower noise fans.

2.3.6 Cost Analysis

Modification		
Basic Cost		$13,777
Modification Cost	$20,907	
Engineering	17,333	
Test	5,888	
Documentation	2,160	
Program Management	2,228	
Total Modification Cost		$48,516
Total Cost		$62,293
New Development		
Cost	$212,000	
Weight	119 pounds	
Data Source	Orbiter-vendor quote	

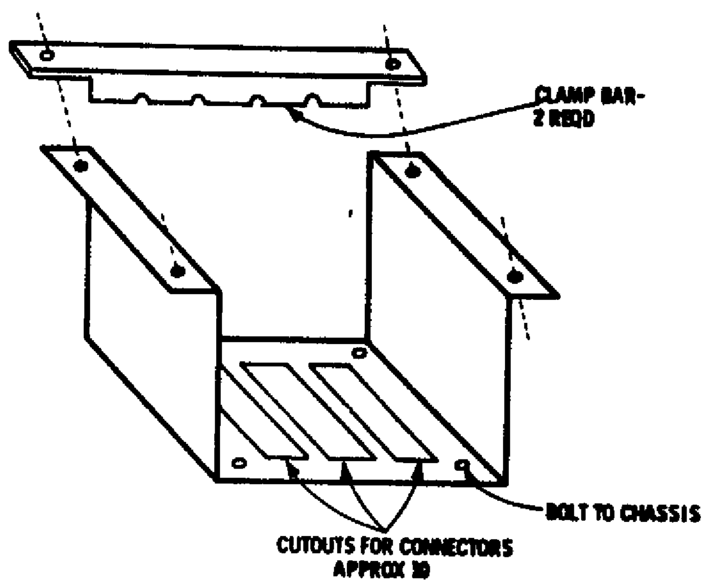

Figure 2.3-3. Circuit Card Edge Clamping Assembly

52-23-07.1

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME PDP-8E Computer NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EX/D			COST $ MAT'L	LABOR	TOTAL
		CHanges Identified													
		Clamp Wires & Cables			1.00	.50							5.00		
		Conformal Coat 10 PCB's			12.50	2.00							30.00		
		Fab. Bezel		20.00	1.00	.50							25.00		
		Cut & Screen Vents on Sides		4.00		.50							15.00		
		of Chassis													
		Repaint Entire Units with				1.00							75.00		
		Clear "Approved" Paint													
		Replace all Knobs & Switches		40.00	2.50	3.00							250.00		
		& Pin Shafts		8.00									3.00		
		Replace "Some" Components			20.00								100.00		
		Replace all Wire w/TFE													
		Backplane			4.00								8500.00		
		Harness & Hookup				40.00	80.00						60.00		
		Replace all Retraction Knobs		40.00	3.00	1.00							100.00		
		& Card Guides													
		Replace all Hardware with			15.00								100.00		
		NYLOC Stainless													
		Strip & Refinish all Cad			20.00	5.00							150.00		
		Plated Parts													
		Replace Fans	2	8.00	3.00	2.00	4.00	2.00					250.00		
		TOTAL HOURS													

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LOT SIZE FROM	TO	
		RATE
		O.H.
		TOTAL
		TOTAL
		TOTAL

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME PDP-8E Computer NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD	COST $ MAT'L	LABOR	TOTAL
		Items Required to Accomplish											
		Part 1 Items:											
		Completely Disassemble Exist-						40 00	40 00				
		ing Instrument & Document											
		for Reassembly											
		Reassemble Instrument						20 00	60 00		40 00		
		Test to Original Specs					100 00	40 00					
		Other Support for Above			15 00	20 00		20 00		40 00			
		Operations											
		150 Hour Bake	1					16 00			500 00		
		Fab. PCB Clamp Bar -	2	2 00		20					10 00		
		Fab. PCB Card Cage	1	8 00		80			8 00		30 00		
		TOTAL HOURS		130 00	97 00	76 50	184 00	138 00	198 00	40 00	1024 00		
		LOT SIZE FROM / TO	RATE										
			O.H.										
			TOTAL								1024 00	1066 27	2090 [illegible]
			TOTAL										
			TOTAL										

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SHEET 2 OF 2 BY STATA

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2.3.7 EC006M Delta Modifications Requirements Summary

1. Provide for non-operating vacuum and thermal capability.
   a. Respecify and replace 150 electronic parts for vacuum and temperature.
   b. Replace lubricants in two fans.
   c. Provide vacuum and thermal test chambers and test time for qualification and acceptance. Current thermal capability is inadequate; no vacuum capability.
2. Provide connector interface for all item-level testing.
   a. Add an external interface test connector (50-pin).
   b. Add a 50-wire test harness.
   c. Patch wire 15 PCB's for 50 test signals to spare PCB connector pins.
   d. Add an internal test connector for 10 wires to P/S assembly.
   e. Add a 10-wire test harness inside P/S module.
   f. Add a hard-mounted signal isolation circuit board
3. Seal the following connectors against moisture.
   a. 40 PCB-to-master interconnect board (printed pins on PCB's).
   b. 14 side-by-side double connectors that interconnect 2 side-by-side PCB's opposite master board connectors.
   c. 6 PCB-to-ribbon harness connectors.
   d. 5 round connectors (5 to 10 pins each).
   e. 6 item interface connector halves.
4. Replace PVC as follows (delta to SEEIR modifications) - 100 loose wires.
5. Human factors modifications:
   a. Repackage power supply and fan unit and installation for maintainability.
   b. Provide silkscreen control identification and operating instructions (22 controls).
   c. Provide captive 1/4-turn rack mounts (4 places).
6. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

2.3.8 Delta Modification Costs

Fabrication	$ 2,233	
Engineering	25,955	
Test	5,649	
Documentation	2,562	
Program Management	1,820	
Total delta modification cost		$ 38,219

2.3.9 Data Sources

1. Visual examination
2. PDP-8/E, PDP-8/M, and PDP-8/F Small Computer Handbook, Digital Equipment Corporation (1973)
3. OEM Products and Services Catalog, Digital Equipment Corporation (1972)

2.4 DEWAR

Manufacturer: Cryogenic Associates

Model Number: IR 90

Cost: $1000

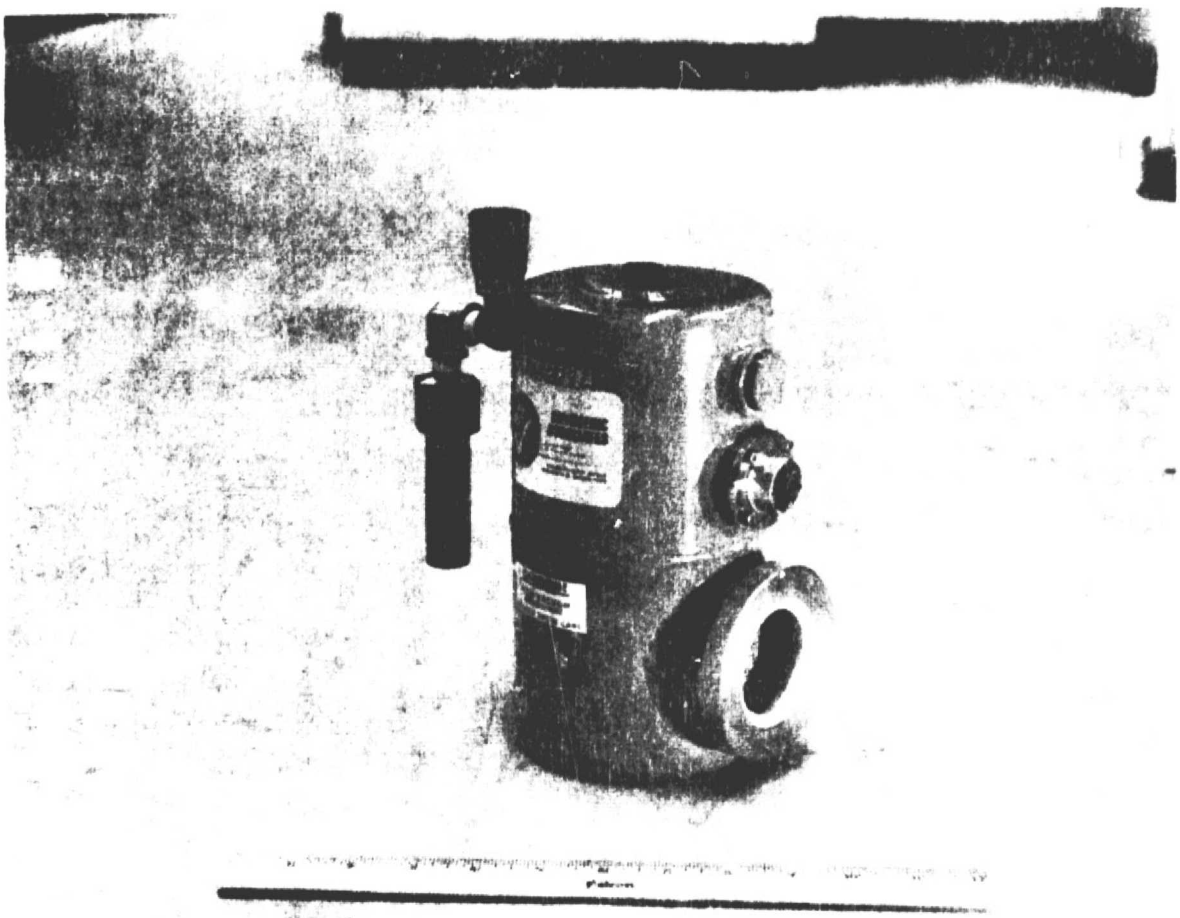

Figure 2.4-1. Cryogenic Associates IR 90 Dewar

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2.4.1 Description

Cryogenic Associates' IR Series of cryogenic dewars provides an extremely wide and flexible line of some 125 basic designs (with hundreds of modifications) for research and/or operational use in the cooling of infrared detectors--individually or in array.

Available in liquid nitrogen shielded helium or neon dewars, nonshielded liquid helium dewars and liquid nitrogen dewars, the IR Series also offers choices in side-lookers, down-lookers, up-lookers and combinations thereof. Selections can also be made between stainless steel or aluminum construction in combination with low thermal conductivity plastic in the support system for dimensional stability.

All dewars are complete with vacuum casing burst disc, evacuation valve, electrical feed-throughs, pressure relief valves, standard fill connections and easy access for detector installation.

2.4.2 Performance Characteristics

LN_2 capacity: 0.6 liters
Holding time: 24 hours

2.4.3 Physical Characteristics

Dewar diameter: 4.25 in. (10.8 cm)
Dewar length: 8.5 in. (21.6 cm)
Weight (empty): 1.5 lb (0.68 kg)
Weight (full): 2.5 lb (1.0 kg)

2.4.4 Suitability Analysis

Heliarc welded aluminum tank. Super insulation within evacuated volume between two containers. Low conductivity innter tank supports.

Requires special mounting adapter to tie down to Spacelab structure.

	Disposition: Accept	Verify	Unaccept
MATERIALS			
Aluminum Foam plug Bakelite knob on valve Glass face over sensor mounting			
VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Nitrogen input line requires special support.			X
Specimen access port does not have positive locking on threaded access port.			X
CONTAMINATION GENERATION			
Tank requires overboard vent for relief evaporating nitrogen.			X
TOXICITY			
No prohibited toxics or large quantities of potential toxic generators identified	X		
ATMOSPHERE			
Can operate in any pressurized atmosphere.	X		
AMBIENT TEMPERATURES			
No constraints in habitable environment.	X		
ZERO-G EFFECTS			
Two-phase cryogenic liquid containment requires special design and development. Existing design can not assure gas instead of liquid flow out through relief valve.			X
OPERABILITY			
Protrusion protection depending upon mounting location.		X	

2.4.5 Modifications

It was concluded that modification of this unit for operation in the Spacelab would not be cost effective. The IR-90 stores the cryogen as a two-phase fluid--liquid nitrogen sits at the bottom of the dewar and gaseous nitrogen at the top. As the nitrogen boils from heat leakage through the walls of the dewar, gaseous nitrogen flows out the vent port relieving the pressure in the container. In zero-g there are no forces on the liquid cryogen to retain it in the bottom of the tank. Liquid or gaseous cryogen can flow out the relief vent in zero-g, dumping liquid cryogen overboard before its cooling effect has been used. Special design techniques must be used to retain liquid cryogen in the tank. Electrophoresis and capillary action have been proposed as two possible retention approaches. Both approaches are only in prototype design stages. Major development is required before an operational unit could be flown on Spacelab. It is not apparent that any portion of the available tank could be used on the new tank. Therefore, this unit can be obtained only as a custom-built unit. Revised design information and modification costs have not been generated. Custom-cost data are presented.

2.4.6 Cost Analysis

New Development

Cost. $1,310,000
Weight . . . . 5 pounds
Complexity 1.00
State-of-the-art factor 5
Data Source . . . . Space Station Cryogenics

2.4.7 EC006M Delta Modifications Requirements Summary

A delta modification summary was not generated inasmuch as modification is meaningless as explained in 2.4.5, above.

2.4.8 Data Sources

1. Visual examination

2. Cryogenic Associates, Inc., drawing number 01575, IR-90, Infrared Cooling Dewar (7/31/70)

3. Cryogenic Associates Sales Brochure

2.5 DISPLAY TERMINAL

Manufacturer: Research, Inc.
Model Number: 3300
Cost: $1580

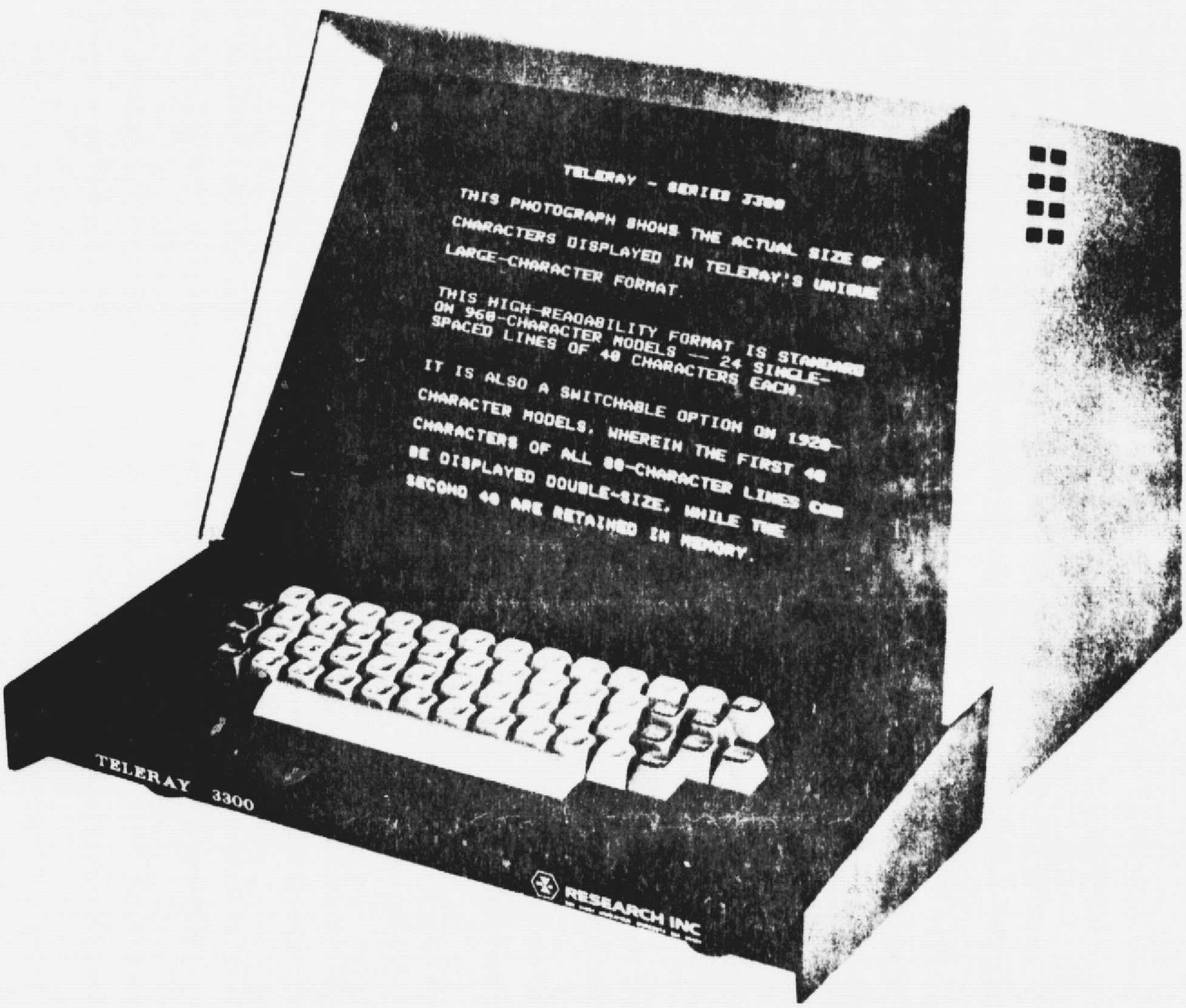

Figure 2.5-1. Research, Inc. Display Terminal

2.5.1 Description

The Series 3300 TELERAY is a character-oriented interactive terminal. Screen capacity is 1920 characters, maximum, and the display is refreshed by a parallel-organized MOS shift register memory. The character generator is an MOS read-only memory. A high-resolution 12-inch TV monitor provides the video display. The optional keyboard utilizes non-contacting solid-state switching. Regulated power supplies are self-contained.

Data are entered on the bottom line of the display and scroll to the top similar to teletype printout. Line feed (auto or manual), carriage return (auto or manual), stop bits (one or two) and parity (odd, even, high or low) are jumper-set.

TELERAY displays a 64-character subset of USASCII code. The keyboard generates 98 characters (64-character subset, 32 control characters, DELETE and ALT MODF). Automatic display "foldover" is provided; that is, upper-case equivalents are displayed for the displayable characters in columns 6 and 7 of the USASCII chart. A REPEAT key allows any generated code to be continuously repeated at a 15-per-second rate. A BREAK key commands the communications line to the spacing level. LINE FEED shifts all data up one line--top line scrolls off. RETURN moves cursor home (first column, bottom line). BELL generates an audible tone.

2.5.2 Performance Characteristics

INTERFACE:	EIA Spec RS-232-C, TTL (Neg) and 20 ma current loop
COMMUNICATION:	Asynchronous
CHARACTER FORM:	5 x 7 dot matrix
SCREEN REFRESH RATE:	60 Hz
CHARACTER COMPOSITION:	10- or 11-bit word: 1 start bit 7 data bits 1 parity bit 1 or 2 stop bits
DISPLAY FORMATS:	24 lines x 72 or 80 characters 24 lines x 40 characters 12 lines x 72 or 80 characters
DATA TRANSFER RATE:	110 to 2400 baud
MODES:	Full or Half Duplex (switchable) Local or Remote (switchable)
KEYBOARD:	Non-contacting, solid-state switching, ASCII-coded

2.5.3 Physical Characteristics

Dimensions: 15-1/2 inches wide by 13-1/2 high by 23-1/2 deep (39.4 by 34,3 by 60 cm)

Weight: 39 pounds (17.7 kg)

2.5.4 Suitability Analysis

CONSTRUCTION. Unit consists of large CRT (12 inches), a keyboard and electronic components mounted on two large fiber-boards, and a metallic chassis (Figure 2.5-2). The entire unit is enclosed in a large sheet steel case. A single circuit board contains approximately 90 integrated circuit chips. Larger components are attached separately to the chassis or other surfaces. The unit is designed to be bench-mounted.

	Disposition: Accept	Verify	Unaccept
MATERIALS			
PVC ribbon cable			
Glass CRT			
ABS plastic keyboard buttons			
Cadmium-plated chassis			
Phosphorus in CRT			
SHOCK, VIBRATION, ACCELERATION AND ACOUSTIC ENVIRONMENT			
Unit not ruggedly constructed (Figures 2.5-2 and -3)			X
CRT support appears inadequate			X
Two large Mallory capacitors are cantilevered from side panel			X
Powdered-core high-voltage transformer is not cushioned (Figure 2.5-4)			X
Large electrolytic capacitor mounted on side panel and strapped to rear panel			X
Large circuit board can oil can			X
RF transformer support inadequate			X
Lead-supported components			X
ELECTRICAL POWER			
110 to 125 vac, 60 Hz, 62 watts	X		
DATA MANAGEMENT COMPATIBILITY			
EIA Spec RS-232-C TTL Neg		X	
EMI SUSCEPTIBILITY AND RADIATION			
No internal shielding; metal case may be adequate shielding to protect operation		X	
Horizontal oscillator, high-voltage power supply and sweep circuits will affect surrounding instrumentation			X
No connector shielding			X

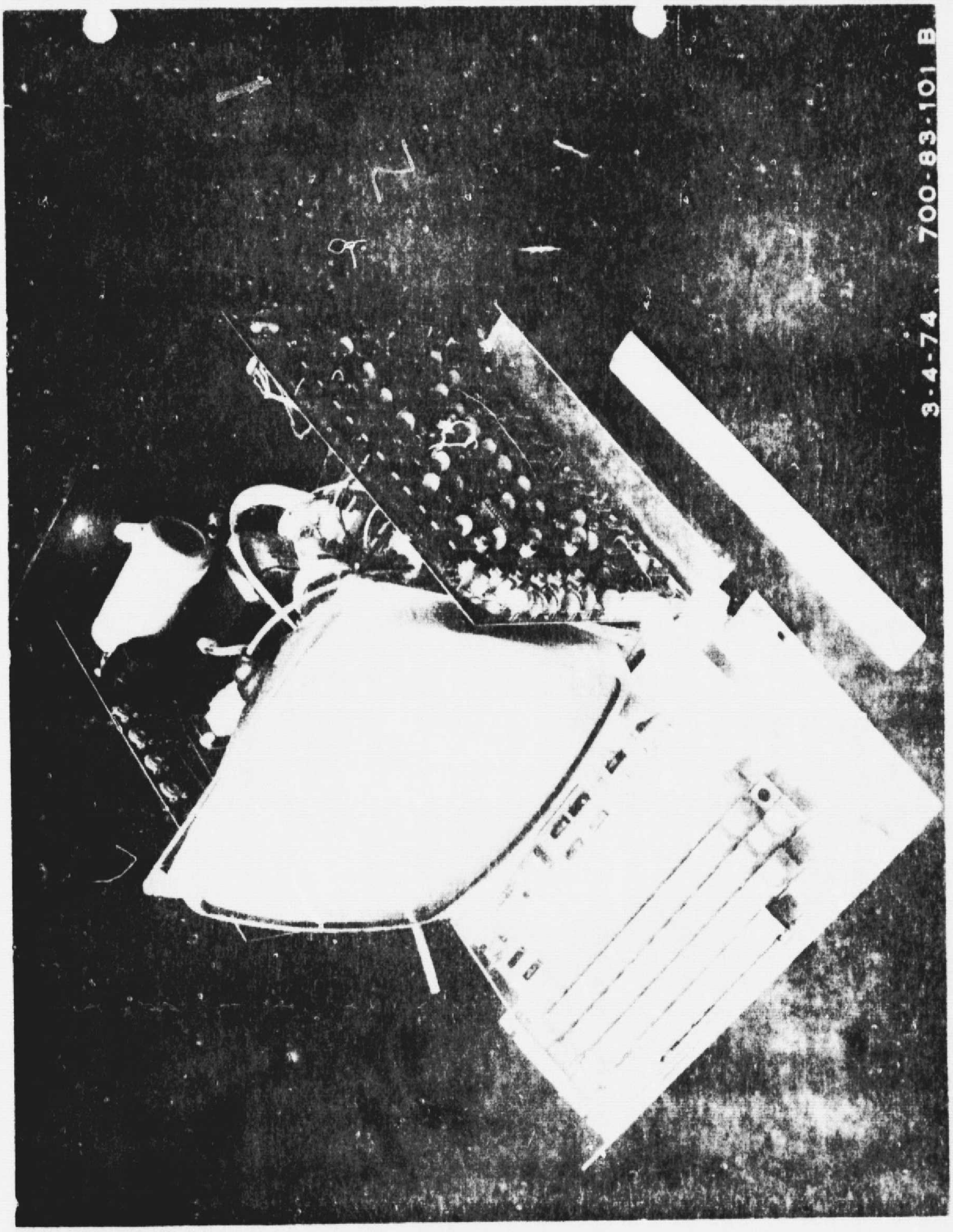

Figure 2.5-2. Exposed View of Research Display Terminal

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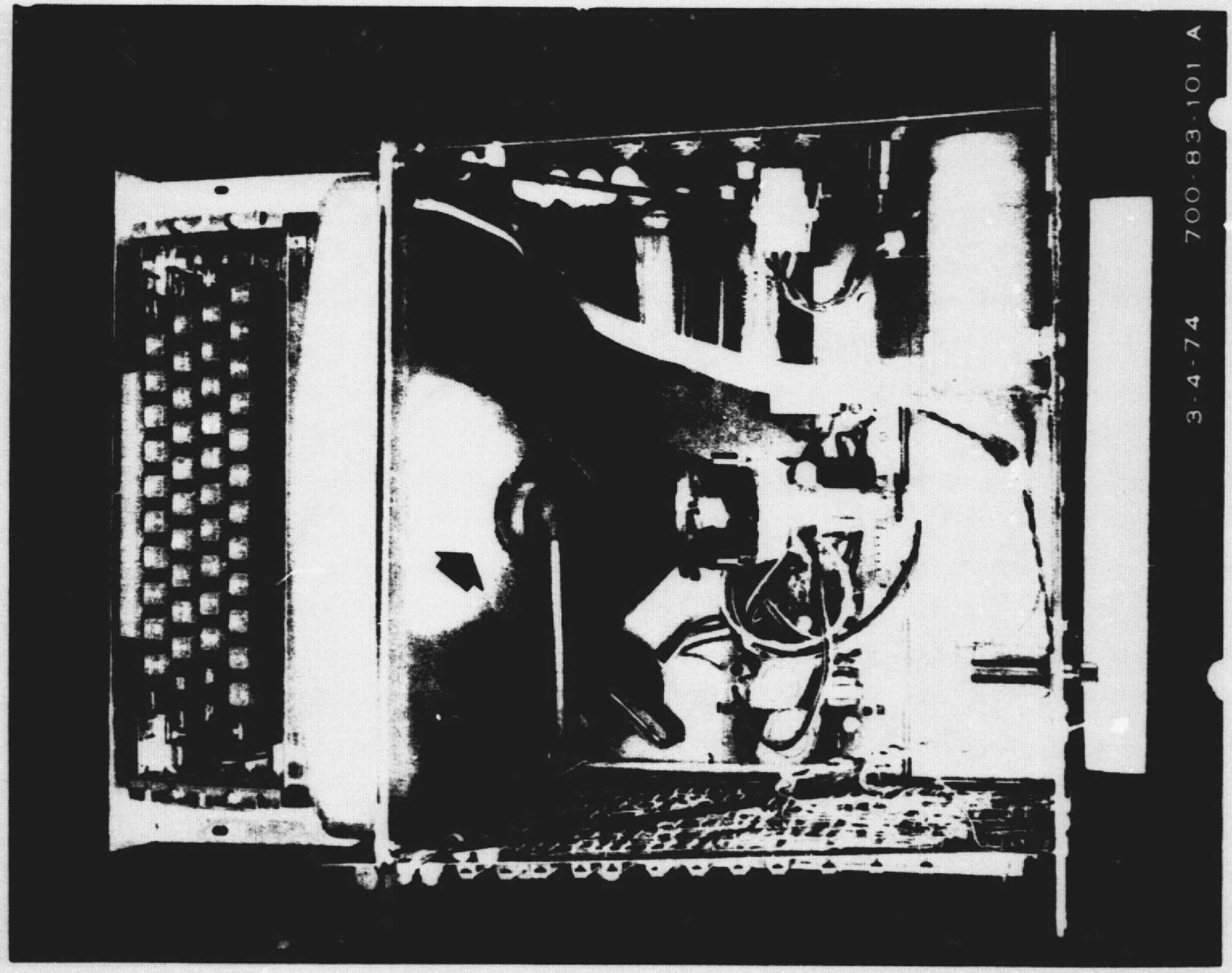

Figure 2.5-3. Display Terminal - View From Above

Figure 2.5-4. Powder Core Transformer and Transistor Convector

	Disposition		
	Accept	Verify	Unaccept
FLAMMABILITY			
Plastics			X
PVC insulation			X
TOXICITY			
Cadmium-plate chassis			X
Phosphorus in CRT		X	
CONTAMINATION GENERATION			
Flaking around CRT high-voltage connection (see arrow on Figure 2.5-3)			X
Glass fragments			X
ATMOSPHERE			
Compatible with Spacelab atmosphere	X		
AMBIENT TEMPERATURES			
Compatible with expected Spacelab temperature ranges	X		
EQUIPMENT COOLING			
Unit relies entirely upon natural convection for cooling. Note finned heat sink connector on power transistor (Figure 2.5-4).			X
ZERO-G EFFECTS			
No gravity-dependent functions	X		
OPERABILITY			
Does not have protrusion protection			X

2.5.5 Modification

The low level of structural integrity of the existing instrument mandates a new case or packaging configuration which will have the additional capability of being rack-mounted.

Figure 2.5-5 depicts the rack-mounting front panel of the standard 19-inch width, with a heigh of 17-1/2 inches, and a thickness of 1/8 inch. The panel is cut out in the middle to clear the CRT tube face. The frame which holds the plastic screen, because of its geometric complexity, is made from the existing instrument case, cut at the proper line and attached with nutplates to the front panel. A stiffener made from aluminum extrusion (L-shape) is bonded to the plastic screen (bottom edge). The keyboard enclosure is attached to the front panel below the screen assembly and is secured with a sheet metal wraparound which (1) strengthens the keyboard protrusion from the panel, and (2) provides a structure to which rubber or plastic molding strip may be attached for safety purposes. The wraparound is attached to the front panel with nutplates.

Figure 2.5-6 shows the sheet metal geometry of the instrument case. Although for purposes of clarity, electronic components are not depicted, the case as shown will accommodate all the electronics of the instrument with the exception of the keyboard (Figure 2.5-5). The major electronic assemblies are as follows.

1. CRT Assembly. This includes the cathode ray tube, its mounting structure, an RF transformer, a high-voltage powdered core transformer, and a 3-inch by 6-inch printed circuitboard assembly. Modifications consist of the following: eliminating the existing subchassis and mounting all components to the main chassis shown in Figure 2.5-6; replacing the CRT mounting structure with one heavier and stronger (see Figure 2.5-7); adding an additional clamp to the RF transformer; potting the powdered core transformer in a suitable plastic and securing it to the chassis; mounting the printed circuit assembly as shown in Figure 2.5-8, with attention to Note (1).

2. RH (Logic) Printed Circuit Assembly. This will be mounted on the inside of the RH side panel where shown in Figure 2.5-6. Figure 2.5-8 depicts the epoxy-standoff technique used to strengthen the PC board to prevent "oil-canning." The PC assembly is relocated approximately one inch aft from its former location relative to the CRT assembly.

3. LH Printed Circuit Assembly. This situation is similar to the RH assembly except that the two large capacitor cans are attached to the main chassis with nylon clamps in the same manner as the one large capacitor is attached to the inside of the back panel.

4. Large Power Transformer. This is relocated on the main chassis. Wire lengths remain the same.

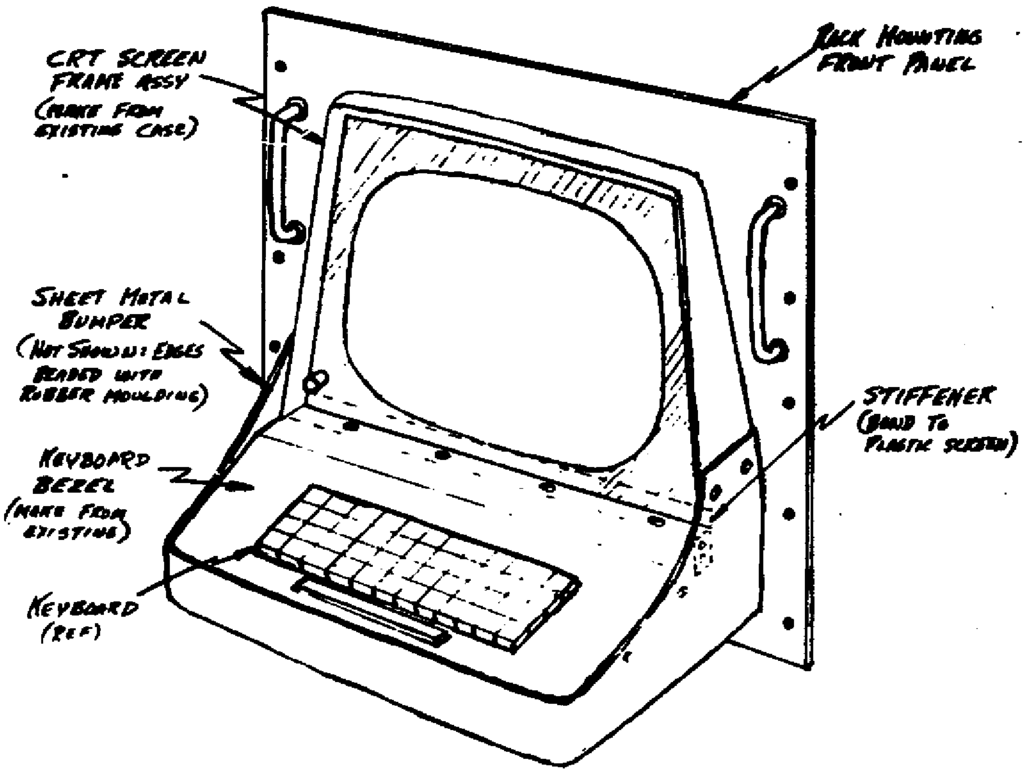

Figure 2.5-5. Front Panel Assembly

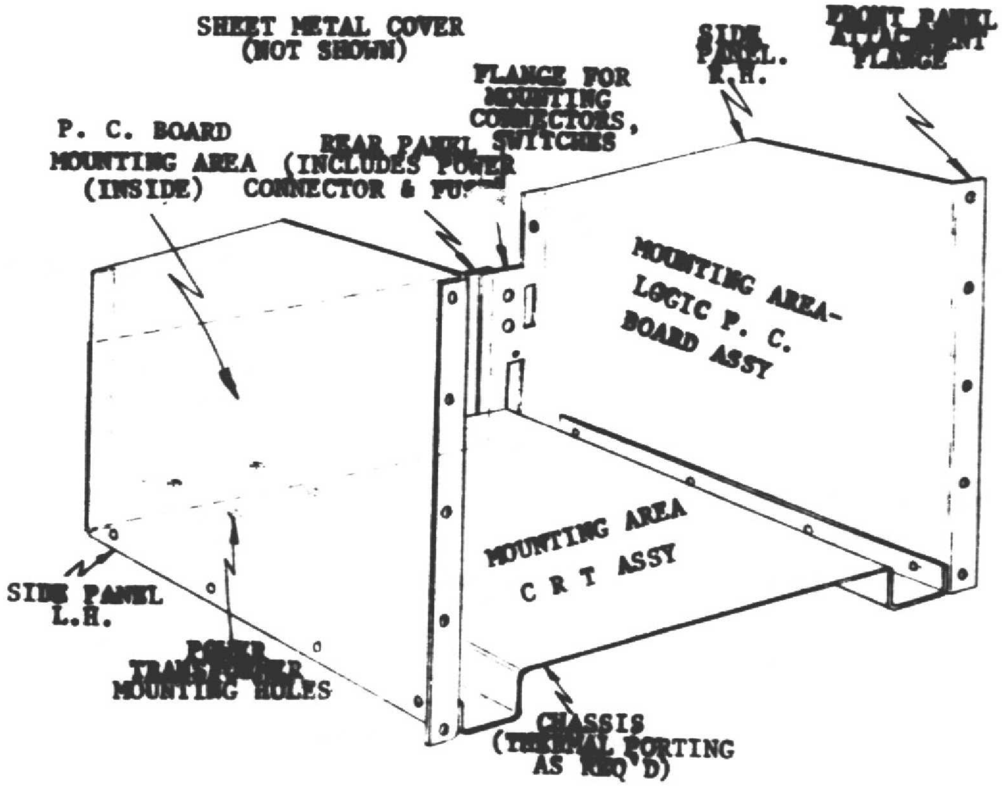

Figure 2.5-6. Case Assembly (Sheet Metal)

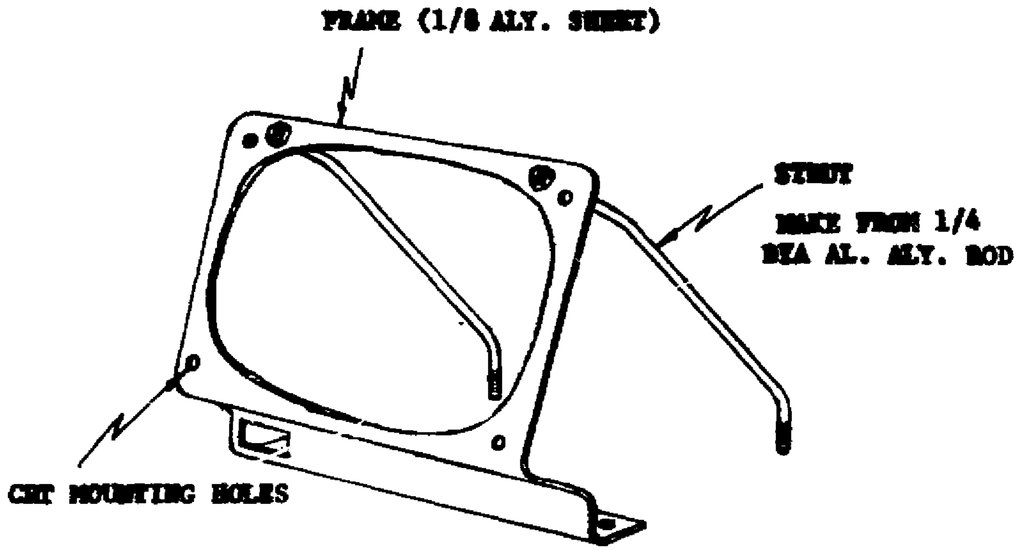

Figure 2.5-7. CRT Mounting Assembly

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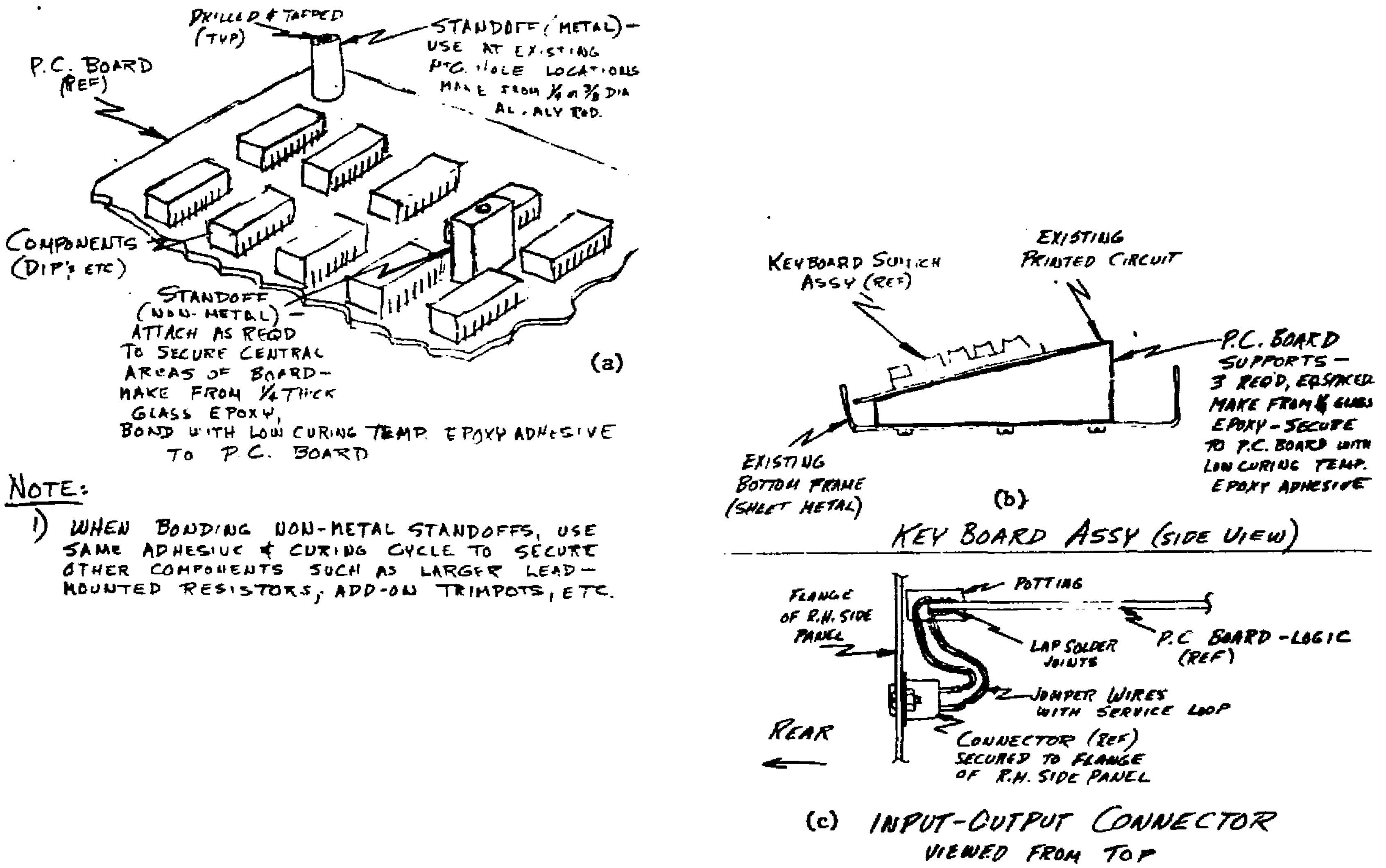

Figure 2.5-8. PC Board Modifications

Miscellaneous Requirements

1. All fastening hardware must be vibration proof.
2. All aluminum surfaces must be anodized.
3. Thermal ports and vents, plus any other apertures, must be covered (on the inside) with metal screen to prevent glass particle egress in the event of CRT breakage.
4. All unsupported cable or wire bundles must be secured with non-metallic clamps.

2.5.6 Cost Analysis

Modification

Basic cost		$ 1,814
Modification Cost		
Fabrication	$ 4,979	
Engineering	19,136	
Test	5,888	
Documentation	2,160	
Program management	1,565	
Total Modification Cost		$33,728
Total Cost		$35,542

New Development

Cost	$503,000
Weight	30 pounds
Complexity	1.0
State-of-the-art factor . .	2
Data source	Space Station - Remote Terminal

2.5.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal range capability.
   a. Respecify and replace 50 electronic parts for vacuum/thermal range.
   b. Add test chamber and test time for qualification and acceptance.
2. Provide connector interface for testing item to replaceable assembly level.
   a. Add one 25-pin external interface test connector.
   b. Add a 25-wire test harness to five replaceable assemblies.
   c. Add a hard-mounted test signal isolation circuit board (10 discretes).
   d. Patch wire test signals on 4 PCB's to spare connector pins.

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ____ ASSEMBLY NAME CRT Terminal-Teleray MD 3301 NEXT ASSY NO. ____ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG. TECH.	COST $: MAT'L	LABOR	TOTAL
		Mod CRT Frame Assy		2 00		25						
		Fab Front Panel		3 00		25				15 00		
		Fab Stiffner		1 00		20				5 00		
		Fab Bumper		2 00		20				10 00		
		Mod Keyboard Bezel & Pan Hard-		3 00		25						
		ware - Handles, Nutplates,								10 00		
		Screws, etc.										
		Assembly				50			6 00			
		CRT Mounting Assy		5 00		25				15 00		
		Fab Chassis		3 00		20				15 00		
		Fab RH Panel		2 50		25				10 00		
		Fab LH Panel		1 50		20				10 00		
		Fab Rear Panel		1 00		10						
		Fab Metal Cover		4 00		25				25 00		
		Hardware, Nuts, Bolts, Screws,		2 00						20 00		
		etc.										
		Assembly							2 00			
		Pot HV XFMR				25			5 00	15 00		
		Mount HV PC Assy & XFMR							3 00			
		Fab Stand Offs-metal		2 00		10				5 00		
		Fab Stand Offs-non-metal		5 00		25				15 00		
		Install Stand Offs & Epoxy				50			5 00			
		parts on P/C Boards										
		TOTAL HOURS										

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		O.H.
		TOTAL
		TOTAL
		TOTAL

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME CRT Terminal-Teleray MD 3301 NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	FAB	ASS'Y	INSP.	TEST	M.E.	MFG. TECH.	EXPD			MAT'L	LABOR	TOTAL
		Conformally coat PCB, Rewire		3	3	1									
		PVC with TFE		50	6 75	1 00		3 75							
		Part II - Operations Requir-													
		ed to Perform Part I.													
		Disassemble Inst. & Doc.						8 00	8 00						
		for Reassembly													
		150 Hour Bakeout					10 00	10 00					350 00		
		Outside Processing of Fab											100 00		
		Parts (Finishes, Etc.)													
		Reassemble Instrument into				5 00		16 00	24 00				20 00		
		New Chassis & Case													
		Tie Down Capacitors & Cables				50			4 00				10 00		
		Test & Troubleshoot					40 00						25 00		
		Certify				8 00	8 00								
		System Support & Expedite				10 00		40 00		30 00					
		TOTAL HOURS		37	9 75	29 50	48 00	67 75	57 00	30 00			655 00		
		LOT SIZE FROM TO	RATE C.H.												
			TOTAL										655 00	3985 64	4640 64
			TOTAL												
			TOTAL												

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3. Seal all connectors/wire junctions against moisture as follows:
   a. Seven internal PCB mounted connectors (no printed PCB pins)
   b. One external interface connector
   c. Note: Assume approximately 100 IC sockets are sealed by the SEEIR encapsulation modification.
4. Replace PVC as follows (delta to SEEIR modifications only): 50 loose wires.
5. Treat for fungus as follows:
   a. Fiber tube around flyback transformer
   b. Materials exposed in deflection circuit transformer (fishpaper)
6. Human factors modifications are as follows:
   a. Add silkscreen operating instructions on panel (53 controls)
   b. Redesign circuit boards for ease of replacement
7. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

2.5.8 Delta Modification Costs

Fabrication	$ 614	
Engineering	15,033	
Test	5,281	
Documentation	2,562	
Program Management	1,175	
Total delta modification cost		$ 24,665

2.5.9 Data Sources

1. Visual examination
2. Research, Inc., Product Information Data, D 812.33B

2.6 EMI/FIELD INTENSITY METER

Manufacturer:	Singer
Model Number:	NM 37/57
Cost:	$13,500

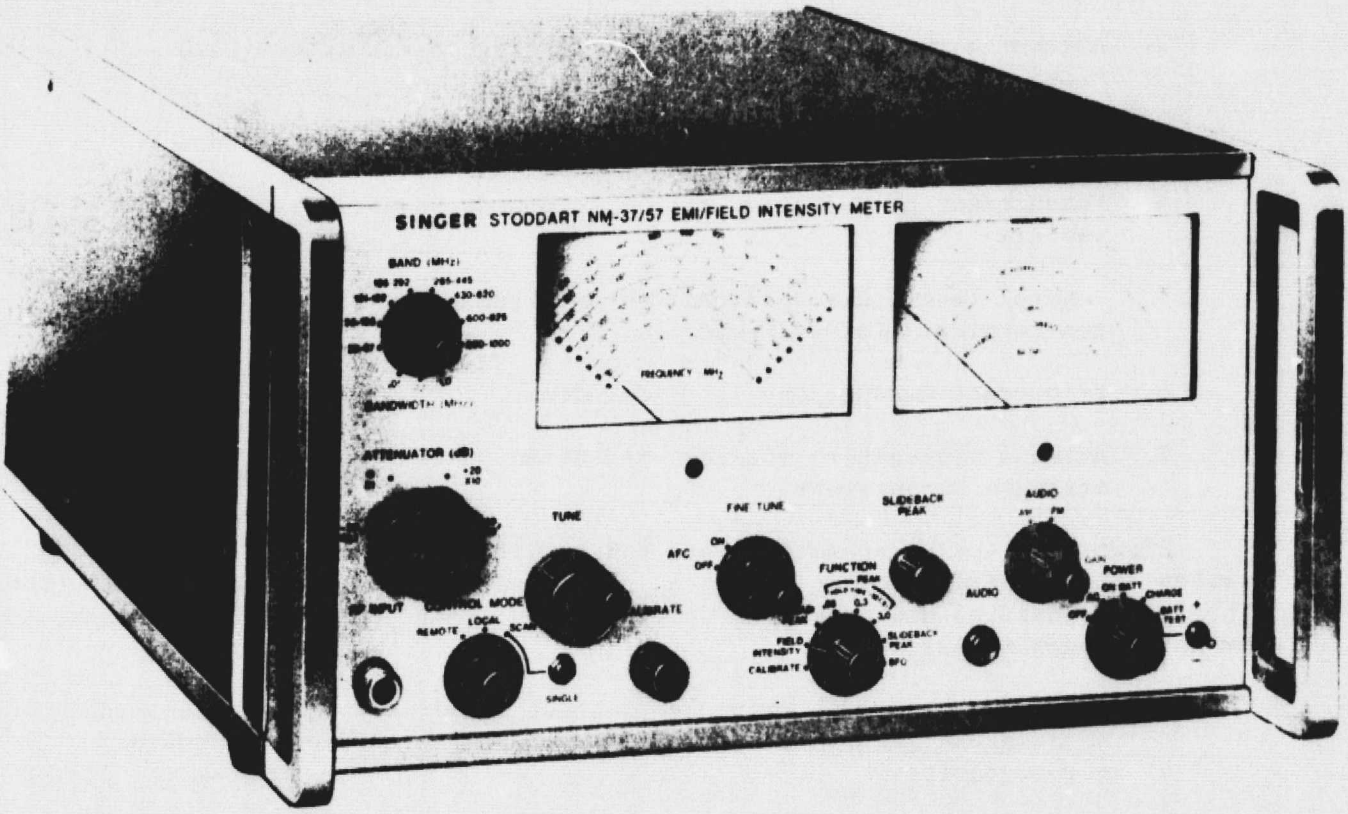

Figure 2.6-1. Singer Electromagnetic Interference/Field Intensity Meter Model NM 37/57

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2.6.1 Description

The NM-37/57 is a programmable, precision electromagnetic interference/field intensity (EMI/FI) meter for the measurement of conducted or radiated RF interference within the frequency range of 30 MHz to 1 GHz in accordance with standard military and commercial EMI test specifications. The instrument performs automatic and semi-automatic testing when supplied with appropriate command signals and provides outputs of signal amplitude and frequency that are suitable for input to a digital data processing system. Some typical applications of the NM-37/57 are:

1. Determining the presence, level, frequency, and characteristics of conducted or radiated RF signals within the frequency range of 30 MHz to 1 GHz.

2. Automatic and semi-automatic EMI testing in accordance with MIL-STD-461A and MIL-STD-826A.

3. Connected to an X-Y plotter for spectrum signature recording.

4. Measurement of radiation from a component, system, or vehicle.

5. General laboratory applications as a tunable, programmable, two-terminal microvoltmeter.

6. RF current measurement in a conductor.

7. Antenna propagation studies, radiation pattern and field strength measurements.

Electronic tuning permits remote tuning without mechanical drive. Activation of the internal electronic scan provision is by a front-panel pushbutton. Three IF bandwidths are provided, permitting quick identification of breadboard or narrow-band signals.

1. The 1-MHz bandwidth provides greatest sensitivity for breadboard signals and permits direct amplitude measurement in microvolts-per-megaHertz.

2. The 100-kHz bandwidth can be used for broadband or narrowband signals.

3. The 10-kHz bandwidth provides greatest sensitivity for narrowband signals and permits improved frequency resolution for closely spaced channels. (A fine-tune control is provided for ease of tuning CW signals when this bandwidth is used.)

2.6.2 Performance Characteristics

Parameter	Characteristic
Frequency Range:	30 to 1000 MHz in 8 bands Band 1: 30 to 57 MHz Band 5: 285 to 445 MHz Band 2: 55 to 105 MHz Band 6: 430 to 620 MHz Band 3: 101 to 192 MHz Band 7: 600 to 825 MHz Band 4: 186 to 292 MHz Band 8: 800 to 1000 MHz
Receiver Type:	Superheterodyne; signal conversion on Bands 1 through 3, dual conversion on Bands 4 through 8
Intermediate Frequencies:	Bands 1 through 3: 20.5 MHz Bands 4 through 8: 160/20.5 MHz
RF Input Impedance:	50 ohms (Type N coaxial connector)
RF Input VSWR:	Bands 1 through 3: 1.25:1 typical, 1.5:1 max. Bands 4 through 8: 1.35:1 typical, 2.0:1 max.
Freq. Scale Accuracy:	True frequency is within ±2 percent of indicated frequency
Voltage Meas. Accuracy:	±2 dB for CW signals ±3 dB for impulse signals
Gain Flatness:	Typically ±1 dB, maximum ±2 dB
Calibrator:	Internal solid-state impulse generator, fixed amplitude, 450 Hz repetition rate
Voltage Meas. Range:	140 dB; 60 dB on meter scale plus 20, 40, 60, and 80 dB attenuator steps
Undesired Response Rejection:	Intermediate frequency rejection: 60 dB minimum Image frequency rejection: 60 dB minimum Spurious rejection: 60 dB minimum (except Band 1 at 2 x 20.5 MHz IF, 40 dB minimum)
Local Oscillator Emission:	Less than 50 picowatts
Shielding Effectiveness:	Typically greater than 100 dB, 80 dB minimum
Automatic Freq. Control:	Typical locking range: Greater than ±100 Hz in 10 kHz bandwidth Greater than ±1 MHz in 100 kHz bandwidth Greater than ±2 MHz in 1 MHz bandwidth
Signal Outputs (simultaneously available):	For a full-scale CW signal
IF (20.5 MHz):	20 mV RMS minimum across 50 ohms BNC connector on rear panel
Log Video:	300 mV ±10 percent peak across 50 ohms, dc to 500 kHz; BNC connector on rear panel

Parameter	Characteristic
Linear Video:	100 mV minimum peak-to-peak across 50 ohms 20 Hz to 200 kHz, for 30% amplitude modulation BNC connector on rear panel
FM Video:	±300 mV minimum peak across 50 ohms, dc to 100 kHz, for ±300 kHz deviation BNC connector on rear panel
Audio (AM or FM):	100 mW typical, 50 mW minimum across 600 ohms 200 to 4000 Hz for 30-percent amplitude modulation Phone jack on front panel
LO Outputs (8) (optional):	Bands 1 through 3: -33 dBm minimum Bands 4 through 8: -20 dBm minimum
Data Outputs (simultaneously available)	
Detector Functions	
Field Intensity (FI) (Average):	Average value of output of the 60 dB logarithmic detector
Quasi-Peak:	Weighted average of output of the 60 dB logarithmic detector. Charge time is 1 millisecond; discharge time is 600 milliseconds
Direct Peak:	Responds to true peak value. Calibrated in RMS of an equivalent sine wave. Selectable hold times of 0.05, 0.3, and 3 seconds
Slideback Peak:	Manual slideback detector with aural null indication
BFO:	Beat frequency oscillator for CW signal reception and tuning aid
FM Discriminator:	±200 kHz deviation
Linear:	Video and audio outputs
Selectable IF Bandwidth:	10 kHz ±10 percent at -3 dB 100 kHz ±10 percent at -3 dB 1 MHz ±10 percent at -6DB (At low end of Band 1 the tolerance of the 1 MHz bandwidth is +10 percent and -30 percent)
Internal Frequency Scan:	Electronically scans any band in one minute, providing outputs to X-Y recorder. Pen Lift provided (isolated contact closure)

Parameter	Characteristic
Programmable Functions:	Electrical programming requirements
Freq. Band Selection:	-12v, 50 mA maximum
Frequency Tuning:	0 to +10v sawtooth (input resistance of 2 kilohms)
Bandwidth Selection	+12v, 14 mA maximum
Detector Function Selection:	+12v, 60 mA maximum
Receiver Gain (Calibrate Control):	+4.8v to +7.2v (input resistance of 50 kilohms)

2.6.3 Physical Characteristics

Dimensions (including handles):

Height: 8-3/4 in. (22.4 cm)
Width: 16-3/4 in. (42.5 cm)
Depth: 18-1/2 in. (47 cm)

Weight:

65 pounds (including battery pack)
(29.5 kg)

2.6.4 Suitability Analysis

CONSTRUCTION

The instrument is all solid state, rugged and portable, and operates from internal rechargeable batteries. Unit is designed for 19-inch rack.

Meter connector bolts approach contact with chassis. See Figure 2.6-2).

Disposition		
Accept	Verify	Unaccept
		X

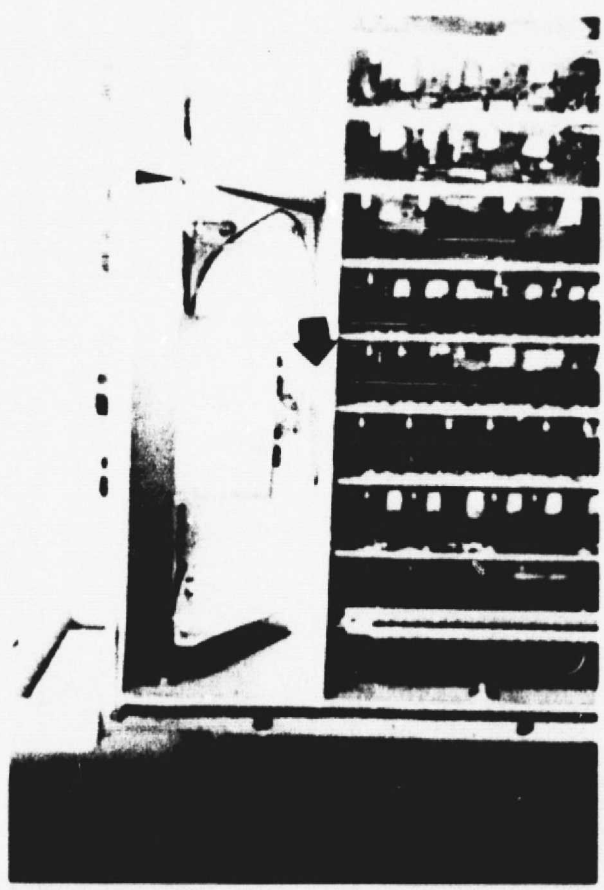

Figure 2.6-2.
Meter Bolts In Close Proximity To Chassis

	Disposition		
	Accept	Verify	Unaccept
MATERIALS			
Glass meter faces			
Sheet aluminum			
TFE wire insulation			
Plastic knobs			
Foam between metal subassemblies			
SHOCK, VIBRATION, ACCELERATION AND ACOUSTIC ENVIRONMENT			
Meets MIL-T-21200, Class 3 non-operating			X
5-15 cps/.06-in. double amplitude for 5 min.			
15-25 cps/.04-in. double amplitude for 5 min.			
25-55 cps/.02-in. double amplitude for 5 min.			
Horizontally along both axes and vertically			
<u>Visual Examination</u>			
Series RF input capacitor cantilevered with heavy lead. See Figure 2.6-3.			X

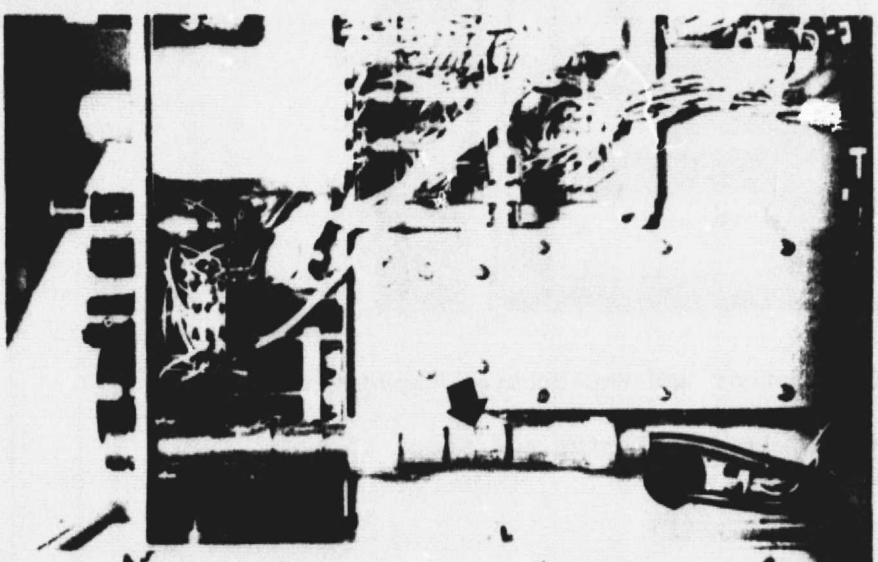

Figure 2.6-3. Series RF Capacitor

	Disposition		
	Accept	Verify	Unaccept
Power transformer and two electrolytic capacitors securely end mounted. See Figure 2.6-4)		X	

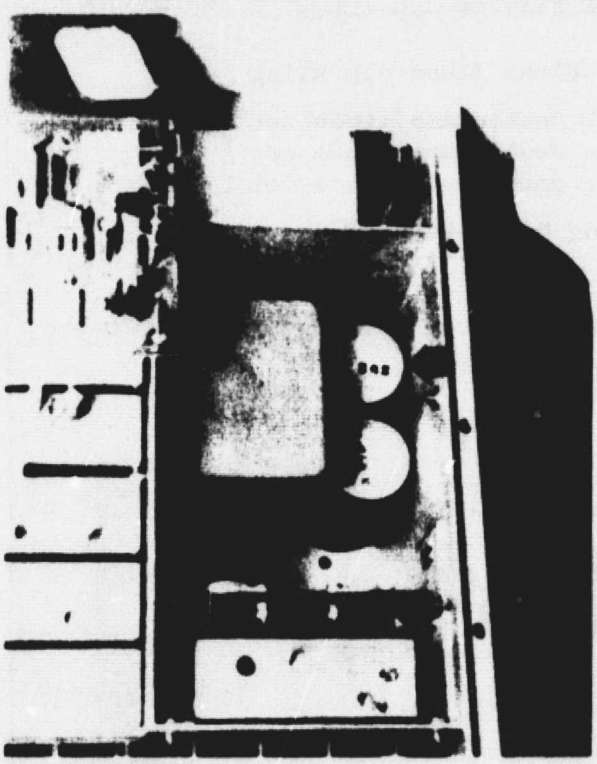

Figure 2.6-4. Transformer and End-Mounted Capacitors

	Accept	Verify	Unaccept
Circuit boards require tightening and stops to keep them from backing out.			X
Cantilevered potentiometers			X
Knobs and screws are not staked.			X

	Disposition		
	Accept	Verify	Unaccept
ELECTRICAL POWER			
115 ± 10v or 230 ± 20v, 50 to 400 Hz	X		
Dissipation: 30 watts			
Batteries not required for Spacelab			
DATA MANAGEMENT COMPATIBILITY			
X-Axis Output 0 to 1v ± 5% across 1000 ohms, 0 to 2v open circuit for any frequency band; BNC connector on rear panel			X
Y-Axis Output 0 to 1v ±5% across 1000 ohms, 0 to 2v open circuit for zero to full-scale meter deflection; BNC connector or rear panel			X
Frequency Readout 10 mV per MHz, 0.3 to 10.0v for full frequency range; accuracy ±2 percent From programmer receptacle on rear panel			X
dB Readout 1 mV per dB, -20 to +120 mV for full voltage measurement range; accuracy ± 2 dB From programmer receptacle on rear panel			X
±12-Volt BCD Programmer Input	X		
SUSCEPTIBILITY AND RADIATION			
RF Gaskets	X		
Heavy case	X		
Internal compartment shielding	X		
Signal returned to chassis internally			X
FLAMMABILITY			
Totally enclosed case	X		
PVC harness insulation		X	
Plastic knobs		X	
Plastic switch wafer		X	

	Disposition		
	Accept	Verify	Unaccept
TOXICITY			
No prohibited toxics or large quantities of potential toxic generators identified	X		
CONTAMINATION GENERATION			
Glass meter faces could shatter			X
ATMOSPHERE			
<u>Pressure</u>	X		
Non-Operating - 3.4 inches Hg (50,000 ft) Operating - 20.58 inches Hg (10,000 ft)			
Meets MIL-T-945, MIL-T-21200, Class 3			
<u>Humidity</u>	X		
Non-Operating - 95 percent RH at 40 C Operating - 95 percent RH at 40 C			
Meets MIL-T-945, MIL-T-21200, Class 3			
AMBIENT TEMPERATURES			
Non-Operating: -62C to +85 C	X		
Meets MIL-T-945, MIL-T-5422, MIL-STD-810, MIL-21200, Classes 2 and 3			
Operating: 0 C to 55 C	X		
Meets MIL-E-16400 Class 4, M-T-21200 Class 3			
EQUIPMENT COOLING	X		
Operational: -15 C to +50 C Non-Operational: -50 C to +75 C			
ZERO-G EFFECTS			
No gravity-dependent functions	X		
OPERABILITY			
Handle guards are square-edged and inadequate protection from knob protrusions			X

2.6.5 Proposed Modifications

Shatterables

Replace glass meter faces with suitable plastic.

9-G Mounting

1. Remove batteries from rear of unit.
2. Replace rack slides with taper pin assemblies and mating guide rails inside rack cabinet per paragraph 10.0 of Design Guidelines.

Protrusion Safety

Install plastic pads of a suitable material on both sides of each handle to meet 1/2-inch minimum radius requirement; see Figure 2.6-5. Secure with suitable adhesive.

Shock, Vibration, Acceleration and Acoustic Environment

1. Replace metal printed circuit card guides with plastic of a more positive security capability; see Figure 2.6-6.
2. Attach bodies of end-mounted capacitors to nearest bulkhead with nonmetallic cable clamps; see Figure 2.6-7.
3. Trim 1/8 inch from meter terminal studs.
4. Replace foam material betweeen subassemblies and on inside of hold-down straps with a suitable material which will accommodate greater variations in subassembly size.
5. Relieve existing cantilever condition of front-panel-mounted RF capacitor and lead assembly with nonmetallic block and clamp. Attach block to chassis and secure capacitor and lead assembly with clamp to block; see Figure 2.6-8.
6. Secure screws and knobs with positive locking features.

EMI Generation

Isolate signal returns.

Materials

1. Replace plastic knobs.
2. Replace plastic wafers in rotary switches with a suitable material such as ceramic.

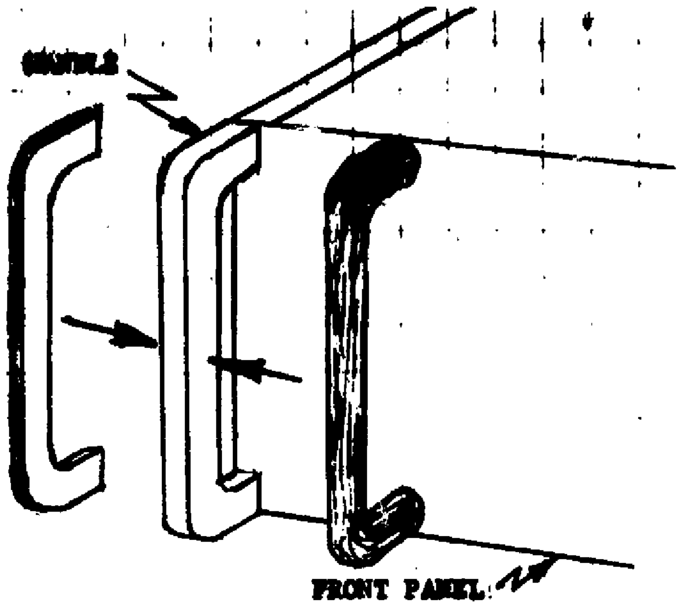

Figure 2.6-5. Pad Additions to Handles

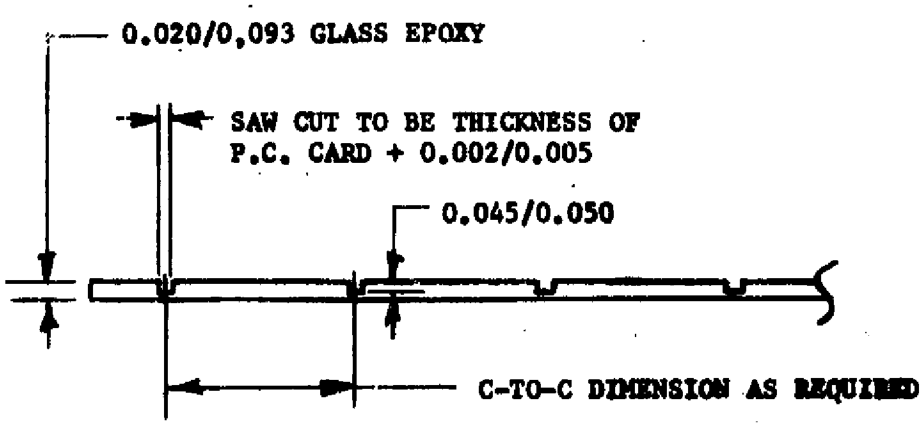

Figure 2.6-6. Replacement Card Guides (Edge View)

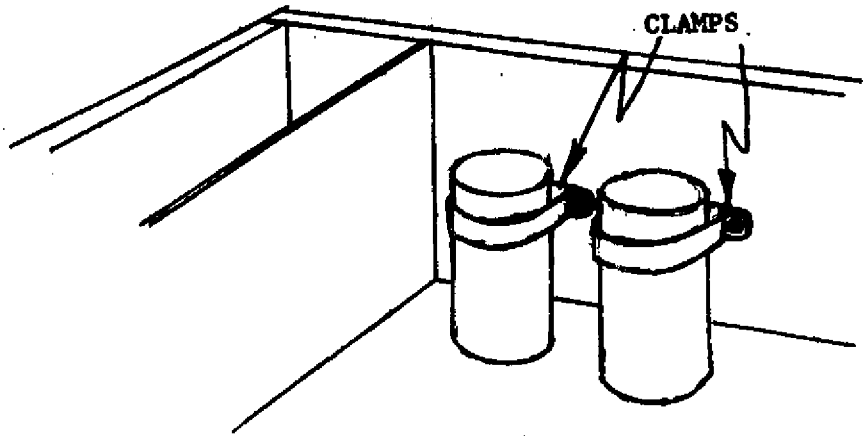

Figure 2.6-7. Capacitor Clamping

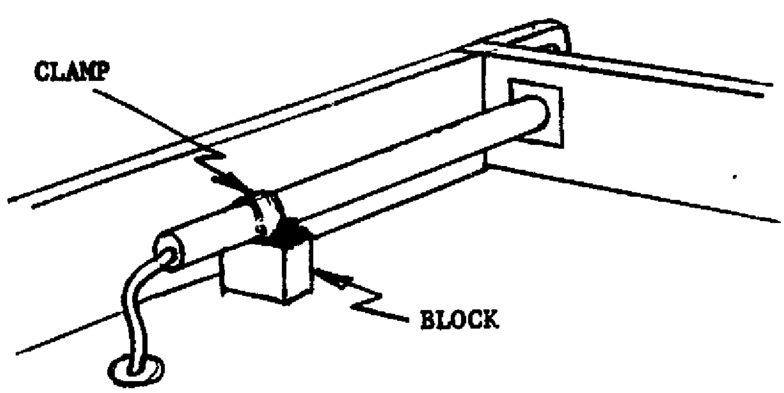

Figure 2.6-8. RF Capacitor and Lead Securing

2.6.6 Cost Analysis

Modification

Basic Cost		$15,499
Modification Cost		
Fabrication	$ 3,367	
Engineering	11,261	
Test	4,416	
Documentation	2,160	
Program Management	1,064	
Total Modification Cost		$22,268
Total Cost		$37,767

New Development

Cost	$187,000
Weight	25 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Lunar Orbital Study - Radio Noise

2.6.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum capability (only).
   a. Respecify and replace 100 parts for vacuum capability.
   b. Add vacuum chamber and test time.

2. Provide capability to externally test item to replaceable assembly.
   a. Add two 50-pin external connectors.
   b. Add a 100-wire test harness.
   c. Add a hardmounted test signal isolation circuit board (40 discretes).

3. Seal the following connectors/wire junctions for moisture:
   a. Seven internal BNC connectors
   b. Seven external input/output connectors
   c. One larger shell-type input/output connector
   d. Twenty-two PCB connectors (printed pins)
   e. Twenty-five single wire RF/coaxial connectors (small snap-in type)

4. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME EMI Field Intensity Meter Singer NM 37/57 NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART I PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	COST $ MAT'L	LABOR	TOTAL
		Replace Glass Meter Faces	2	1 00		20			1 00	10 00		
		with Suitable Plastic										
		Remove Batt.							25			
		Rack Mount Flanges							25			
		Fab. & Install Plastic		1 00		10			1 25	10 00		
		Pads Around Handles										
		Fab. & Replace PC Bd Guides	2	2 00		25			50	15 00		
		Mount Cap to Bulkhead							25	4 00		
		Trim Meter Terminal Studs							25			
		Replace Foam Mat				25			2 00	25 00		
		Mount RF Cap		50					50	4 00		
		Equivalent 150 Hour Bakeout					10 00	10 00		300 00		
		Replace Plastic Knobs	10	10 00		1 00				200 00		
		Replace Plastic Rotar Switch										
		Wafers										
		5 Switches, 11 Wafers			11 00	50				150 00		
		PART II - Operations required										
		to Perform PART I										
		Disassemble Inst. & Doc.						14 00	14 00			
		for Reassembly										
		Reassemble Inst.						8 00	18 00			
		Test & Trouble Sheet					20 00			20 00		
		TOTAL HOURS										

LOT SIZE FROM	TO	RATE
		O.H.
		TOTAL
		TOTAL
		TOTAL

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME EMI Field Intensity Meter Singer NM 37/57 NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD	COST $: MAT'L	LABOR	TOTAL
		Certify				8.00	8.00						
		System Support & Expedite				5.00		20.00		20.00			
		TOTAL HOURS			14.50	15.30	38.00	52.00	38.25	20.00	798.00		
LOT SIZE FROM	TO	RATE											
		O.H.											
		TOTAL									798.00	2569.00	3367.00
		TOTAL											
		TOTAL											

Beckman INSTRUMENTS, INC.

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5. **Human factors modifications as follows:**

   a. Add captive 1/4-turn panel fasteners (4 places)

   b. Add silkscreen operating instructions to panel (13 controls)

2.6.8 Delta Modification Costs

Fabrication	$ 1,657
Engineering	27,857
Test	5,410
Documentation	2,562
Program Management	1,874

Total delta modification cost $ 39,360

2.6.9 Data Sources

1. Visual examination

2. Instruction Manual for Electromagnetic Interference/Field Intensity Meter, Model NM 37/57; Manual Number 1-500783-234; Singer Instrumentation, April 1972.

3. Singer Instrumentation sales documentation

2.7 ELECTROPHORESIS APPARATUS

Manufacturer: Beckman Instruments, Inc.

Model Number: R-100

Cost: $6835

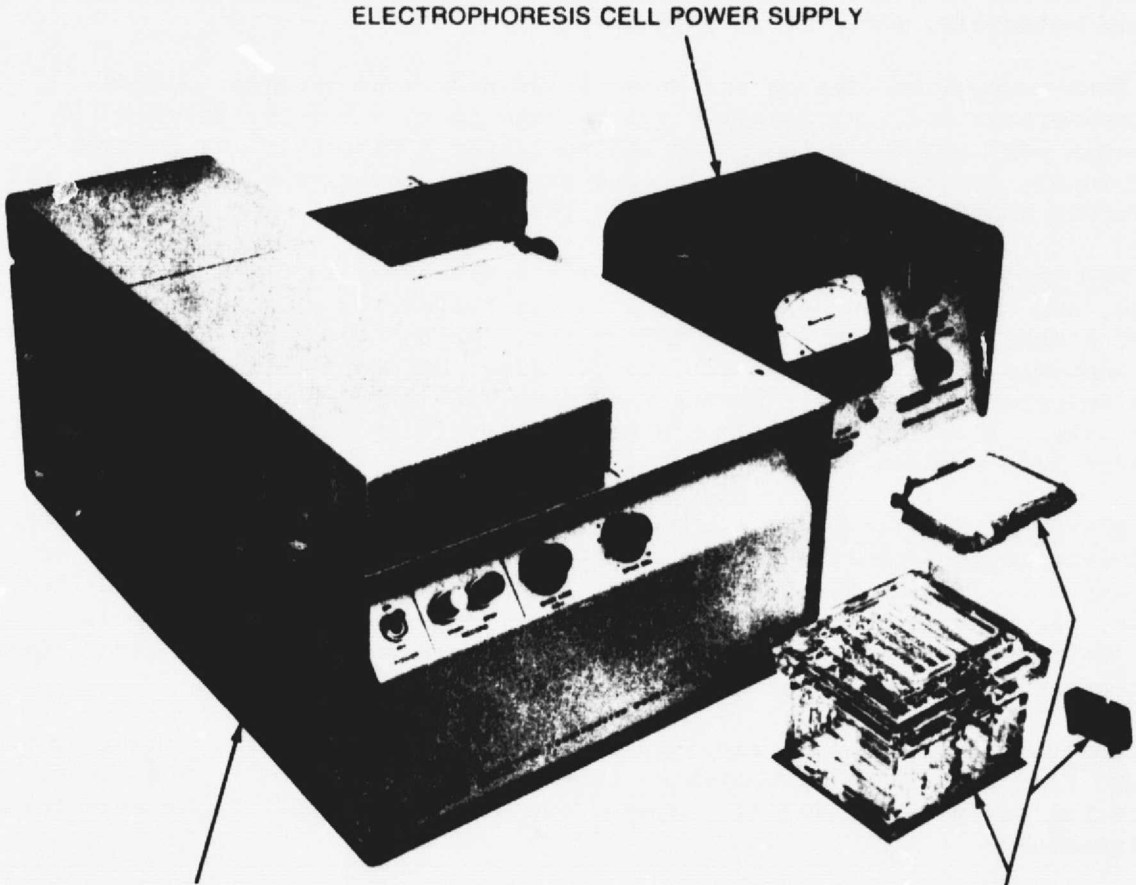

Figure 2.7-1. Elements Of Beckman Electrophoresis System

2.7.1 Description

Zone electrophoresis and quantitation of serum proteins can be done on small samples by this assembly. Reproducible separations are made in 20 minutes by using cellulose acetate membrane.

Eight clinical sera can be produced at one time offering clinical information in serum protein analysis, hemoglobin studies, and evaluations of cerebrospinal fluid, urine, tears and other body fluids. Since cellulose acetate is similar to filter paper used in aqueous systems, it can be applied to all charged materials, ionic or colloidal.

Four components make up the Model R-100 Microzone System: closed electrophoresis cell for compatibly sized and punched strips, Model R-110 Microzone Densitometer which scans and evaluates stained strips, Duostat power supply for required 250-volt constant power and accessory kit with all laboratory supplies for electrophoresis runs.

Microzone Electrophoresis Cell - Consists basically of the cover, a bridge, and the cell vessel divided into two buffer solution reservoirs. Bridge stands directly above the reservoirs. Adjustable tensioning mounts hold membrane flat to prevent pooling of buffer on membrane surface. Wicks are eliminated since hinged guides bend down ends of membrane into buffer reservoirs. A series of baffles in each reservoir isolates electrode reaction products from membrane.

Microzone Densitometer - An automatic scanning, recording, and integrating densitometer; scans cellulose acetate membranes and integrates area of each curve to furnish quantitation of proteins and enzymes from various body fluids. Records directly in optical density units in a range of 0 to 1.5 o.d. Different wavelengths are obtained by interchanging interference filters, which range from 400 to 750 mμ.

Duostat Power Supply - Provides source of regulated power; either constant current from 2 to 50 milliamperes or constant voltage from 0 to 500 volts. Regulation fully automatic; one Duostat can operate two electrophoresis cells simultaneously.

Microzone Accessory - Contains equipment and supplies necessary for serum protein analysis.

2.7.2 Performance Characteristics

Electrophoresis Cell

Separation time	20 minutes
Sample quantity	8
Sample size (serum protein)	0.25 microliter
Buffer	B-2 Barbitol
pH	8.6
Ionic strength	0.075
Fixative stain	Ponceau-S

Densitometer

Wavelength Range

450 to 650 $m\mu$, by replacing interference filters

Measurement Range

0 to 0.5 o.d. unit full scale, adjustable to 0 to 1.5 o.d. units full scale

Optical Accuracy

0.015 o.d. unit ± 1 percent full scale

Slit Width and Length

Width adjustable to 0.1, 0.2, 0.3, and 0.4 mm; length adjustable to 1 and 2.5 mm

Servo Pen System

1.5 seconds full-scale response

Power Supply

Constant Current Output

Current Range	2 to 50 milliamps
Voltage Range	0 to 400 volts
Regulation	±1 percent

Constant Voltage Output

Voltage Range	0 to 500 volts
Current Range	0 to 50 milliamps
Regulation	±1 percent
Ripple Level	0.15 volt rms
Meter Accuracy	±2 percent at full scale

2.7.3 Physical Characteristics

Electrophresis Cell

Dimensions: 4-1/2 in. long x 5 wide x 3-1/4 high (11.5 x 12.7 x 8.2 cm)

Weight: 2 pounds (1 kg)

Densitometer

Dimensions: 19-1/2 in. long x 13-1/2 wide x 10 high (49.5 x 34.2 x 25.4 cm)

Weight: 52 pounds (23.6 kg)

Power Supply

Dimensions: 10-1/4 x 7-3/8 x 8 inches (26 x 18.7 x 20.4 cm)

Weight: 15 pounds, 4 ounces (7 kg)

2.7.4 Suitability Analysis

CONSTRUCTION. Assembly consists of three units. The power supply and densitometer are typical electrical packages with circuit boards enclosed in a metallic case. The electrophoresis cell is a clear plastic container. Densitometer records data with a pen, supported on a cross-member allowing it to tranverse moving paper. All units are designed to be bench top mounted.

	Disposition: Accept	Verify	Unaccept
MATERIALS			
Tenite			
Glass			
P/C wire insulation			
Sheet steel			
Plastic knobs			
Paper			
Felt			
Ink			
Silicone lubricant			
Vacuum tubes			
VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Circuit boards require additional support for vibration environment (Figure 2.7-2)			X
Cell components require storage during boost	X		
Cabling must be tied down			X
Larger end-mounted electrolytic capacitors and transformers			X
Optics, filters, light guide lid on densitometer			X
Power supply components such as vacuum tubes and other large parts require support or replacement			X
ELECTRICAL POWER			
105 to 125 volts; 50 or 60 cps, 100 watts	X		
DATA MANAGEMENT COMPATIBILITY			
Unit current prints out data on strip chart	X		
EMI SUSCEPTIBILITY AND RADIATION			
Power Supply - metal case needs extending to backside			X
Signal return to chassis bypass capacitor			X
Densitometer - metal case; relay operation and BCD logic most potential EMI generators		X	

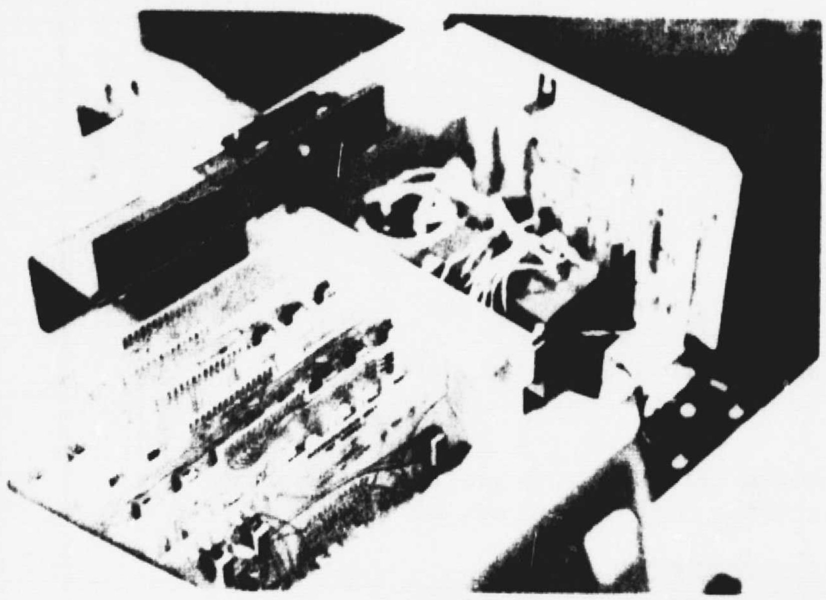

Figure 2.7-2. Densitometer Circuit Board Containment

	Disposition		
	Accept	Verify	Unaccept
FLAMMABILITY			
Nylon card guides			X
Chart paper		X	
PVC insulation			X
TOXICITY			
Buffer solution in cell		X	
CONTAMINATION GENERATION			
Power Supply: meter face			X
vacuum tubes			X
Densitometer: mirrors			X
lamp			X
filters			X
ATMOSPHERE			
Compatible with Spacelab atmosphere	X		
AMBIENT TEMPERATURE			
Compatible with Spacelab	X		

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	Disposition		
	Accept	Verify	Unaccept
EQUIPMENT COOLING			
Fan mounted on rear of densitometer	X		
Power supply requires venting			X
Air circulation across PCB's not definable			X
ZERO-G EFFECTS			
Electrophoresis cell requires gravity to contain buffer solution. Unit is not sealed (Figure 2.7-3).			X

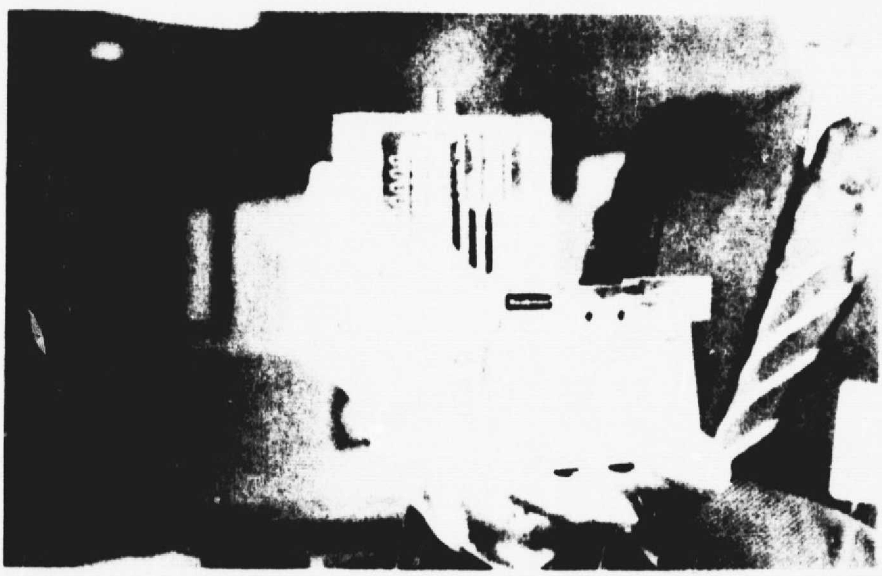

Figure 2.7-3. Electrophoresis Cell With Removable Cover

	Accept	Verify	Unaccept
OPERABILITY			
All corners require rounding depending on mounting location.		X	

2.7.5 Modifications

Significant modification of both the power supply and the electrophoresis cell are required. A power supply consistent with solid-state technology can be purchased in place of the unit referenced. The electrophoresis cell presents more formidable problems. Containment of the buffer solution is totally gravity dependent. The sample is contained in a cellulose acetate strip that is draped across cell partitions and hangs into the buffer solution. A new method of sample handling and cell configuration is required to make it gravity independent. Development of such an approach was considered out of scope for this study. However, it was estimated that such a development would cost approximately $75,000. This value is included in the cost estimate.

All detail modifications are for the densitometer.

Construction

Shatterables. Support lamp per Figure 2.7-4

9-G Mounting/Integrity. Add latch for sample cover (see Figure 2.7-5). Secure adjustment screws with glyptal. Coat approximately 15 printed circuit boards with conformal coating. Replace approximately 200 fasteners with CRES, Nylok design. Secure approximately 10 large components on boards with component clips. Clamp wire cables with suitable clamps in approximately 10 places.

Protrusions and Edges Safety. Place 1/2-inch radius cushion on all edges and corners.

19-Inch Rack Mount Capability. Not applicable.

Shock, Vibration, Acceleration and Acoustics Resistance. Pin two knobs to their shafts. Support circuit boards per design guidelines.

Depressurization Hazard Suppression. Add screened ports to outside per Figure 6.7-6. Cover exhaust fan on rear with CRES screen.

EMI Generation Suppression (R-110). Connect 1N5061 diode across coil of relay K1.

EMI Susceptibility Protection (R-110). Install Corcom Model 2R3 RFI filter in series with incoming 110 vac power line.

Materials Usage

Flaking and Peeling Resistance. Cover all surfaces with an approved clear coating.

Concentrations of Flammable/Unidentified Materials. Replace all wiring with TFE insulated wire.

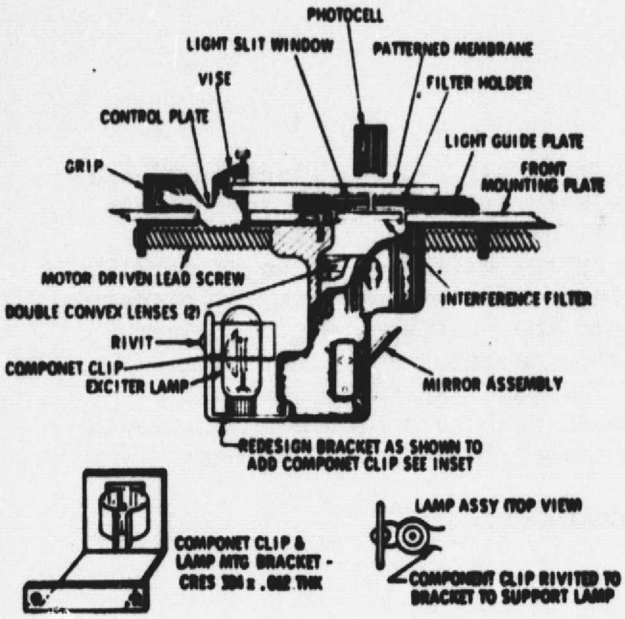

Figure 2.7-4. Densitometer Light Source and Membrane Drive Details

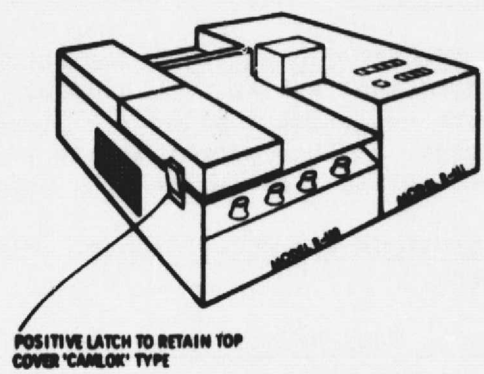

Figure 2.7-5. Densitometer Cover Latch

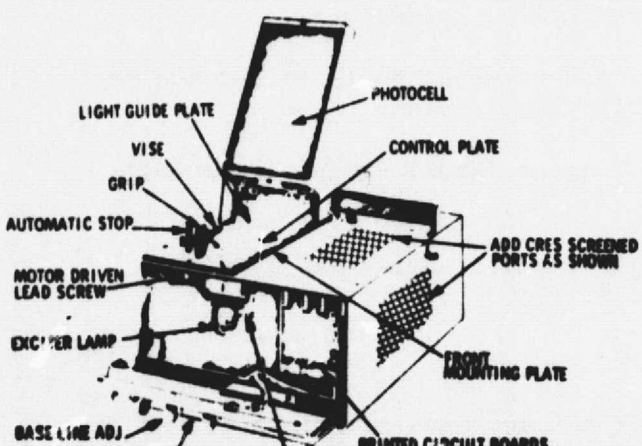

Figure 2.7-6. Densitometer Porting

Non-Prevelant Commercial Materials (Or Warnings on Handling/Usage of Item). Replace all control knobs with metal (approximately two knobs). Replace all pushbuttons with polyimide buttons (approximately seven places). Replace thumb wheel switch with a space-approved switch (available through manufacturer). Felt-tip pens need to be replaced with an approved pen/ink. Replace plastic indicator light lenses (two) with Lexan. Bake out unit 150 hours to remove volatiles.

Resistance to Combustion Ignition. Replace chart paper with a paper coated with an approved coating to resist combustion.

Zero-G Compatibility

Functional Operation. Chart paper requires a spring-loaded takeup reel.

Power Supply

The power supply requires:

1. Installing vacuum tube hold-downs per Figure 2.7-7.
2. Addition of fine stainless screen to rear panel.
3. Fabrication of rack mount bracket and molding per Figure 2.-7-8.
4. Providing screened air ports on side and top of P/S.
5. Pin two knobs to shaft; replace with Vespel.
6. Fabricate meter cover.
7. Rewire with TFE.
8. Change 30 fasteners to CRES/Nylok.
9. Apply clear overspray.

2.7.6 Cost Analysis

Modification

Basic Cost		\$ 7,847
Modification Cost		
Fabrication	\$14,280	
Engineering	49,000	
Test	35,872	
Documentation	2,160	
Program Management	5,016	
Total Modification Cost		\$106,388
Total Cost		\$114,175

C-2

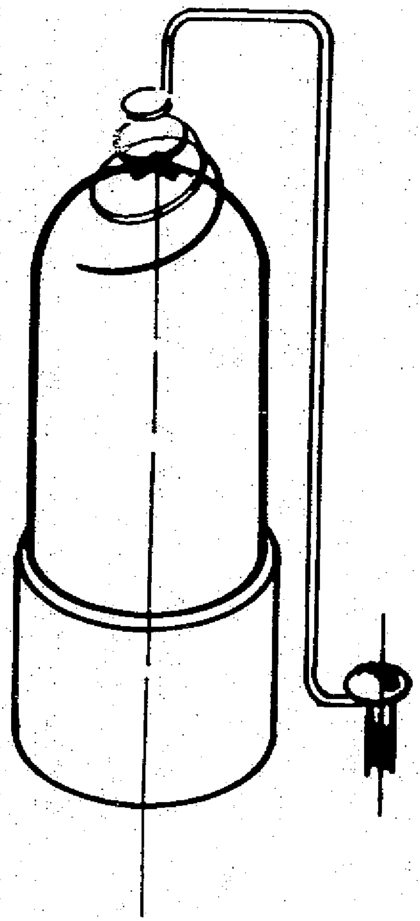

Figure 2.7-7. Vacuum Tube Hold-Down

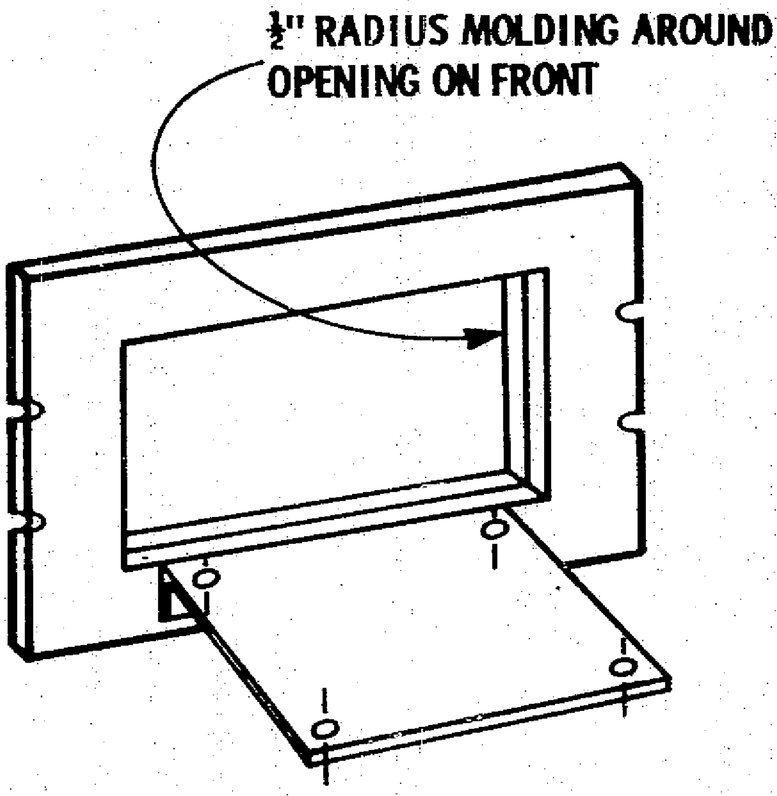

Figure 2.7-8. Rack Mount Bracket - Aluminum Alloy 0.125 Thick

52-23-07.1

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. R-110 & R-111 ASSEMBLY NAME Densitometer/Digital Integrator NEXT ASSY NO. ____ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	COST $ MAT'L	LABOR	TOTAL
		Fab. Lamp Bracket	1	2 50	50	25				4 25		
		Add Latch to Cover		1 00		20				8 20		
		Secure Adjust Screws			1 00	25	1 00			3 00		
		Conformal Coat PCB's	15		18 75	3 00				45 00		
		Replace Hardware w/SS NYLOC	200		30 00	12 00		12 00	12 00	50 00		
		Install Clip for LG. Comp.	10	50	1 00	50				2 50		
		Secure Cables W/Clamps	10	1 00					2 00	5 00		
		Fab. & Install Protection		8 00		2 00			8 00	50 00		
		Pin Knobs to Shafts	2	50		10				1 00		
		Fab. Ports & Screen	2	4 50	1 00	25				5 00		
		Screen Fan Port	1	1 25	50	10				2 50		
		Install IN5061 Diode				10	10		50	1 00		
		Install Corcom Mod. ØR3		1 00		25	1 50		2 50	10 45		
		Over Spry Approved Coating				1 00				61 00		
		Rewire W/TFE	150		15 00	10 00		25 00	25 00	25 00		
		Replace Knobs W/Metal	2		1 00	10				6 50		
		Fab. & Replace Buttons	7	7 00	1 15	70				175 00		
		Replace T-Wheel	1	2 00		75			1 00	23 00		
		Replace Felt Pens	2			20			2 00	50 00		
		Fab. & Install Lexal Lens	2	2 00	50	20				10 00		
		150 Hour Bake						16 00		500 00		
		Replace Paper W/Substitute								50 00		
		Fab Brackets as Required		8 00		2 00			6 00	100 00		
		TOTAL HOURS										

	LOT SIZE FROM	TO	
Beckman INSTRUMENTS, INC.			RATE
			O.H.
			TOTAL
SHEET 1 OF 2 BY STATA			TOTAL
			TOTAL

Space Division
Rockwell International

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52-22-07.1

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. R-110 & R-111 ASSEMBLY NAME Densitometer/Digital Integrator NEXT ASSY NO. ________ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD			COST $ MAT'L	LABOR	TOTAL
		Other Support				12 00	20 00	18 00	12 00	18 00					
		Install V.T. Hold Downs	5	1 00	50	25							10 00		
		Fab. SS Screen (Rear Panel)		1 25		15							4 00		
		Fab. Rack Bracket & Molding		6 00		25							20 00		
		Fab. Ports & Screen	3	4 00		30							8 00		
		Pin Knobs	2	30		10							30		
		Fab. Knobs - Vespel	2	2 00		20							50 00		
		Fab. Meter Cover		2 50		25							15 00		
		Rewire W/TFE	50		5 00	3 50		4 00	4 00				7 50		
		Replace Fastners w/SS NYLOC	30		4 50	75		1 00	1 00				7 50		
		Clear Overspray	SR			50							35 00		
		Other Support for P.S.				4 00	8 00	2 00	3 00	2 00					
		TOTAL HOURS		56 30	80 40	56 20	31 00	78 00	79 00	20 00			1345 70		
		LOT SIZE FROM / TO	RATE												
			O.H.												
			TOTAL										1345 70	5433 88	6779 58
			TOTAL							& Cell					7500
			TOTAL												14280

Beckman INSTRUMENTS, INC.

SHEET 2 OF 2 BY STATA

Space Division Rockwell International

New Development

Cost	$186,000
Weight	30 pounds
Complexity	1.50
State-Of-The-Art Factor . . .	4
Data Source	Space Station Exp. 5.13

2.7.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal range capability.
   a. Respecify and replace 120 electronic parts for vacuum/thermal range.
   b. Provide test chambers and test time for acceptance and qualification.
   c. Replace lubricants in fan and pen motors.
2. Provide an external test connector to test item to replaceable assemblies.
   a. Add a 50-pin external interface connector.
   b. Add a 50-wire test harness.
   c. Add a hardmounted test signal isolation circuit board (20 discretes).
   d. Patchwire four test signals per PCB for 10 PCB's to spare PCB connector.
3. Seal the following connectors/wire junctions against moisture:
   a. Ten PCB's to master board connectors (printed PCB pins).
   b. Four internal connectors.
4. Incorporate the following loose parts into the densitometer:
   a. Power supply
   b. SEEIR electrophoresis cell design (snap in/out).
5. Replace PVC as follows (delta over SEEIR modifications):
   a. 200 loose wires (densitometer and P/S sections)
6. Human factors modifications as follows:
   a. Add silk screen operating instructions to panels (assume 10 total controls).
   b. Replace densitometer access cover hinge with friction type.

7. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

2.7.8 Delta Modification Costs

Fabrication	$ 1,240	
Engineering	22,944	
Test	5,778	
Documentation	2,562	
Program Management	1,626	
Total delta modification cost		$ 34,150

2.7.9 Data Sources

1. Visual examination
2. Beckman Instructions, 015-083618A, Model R-101 Microzone Electrophoresis Cell, Instruction Manual, August 1972
3. Instruction Manual, RD2-IM-6, Regulated Power Supply, May 1965
4. Beckman Instructions 015-083614, Troubleshooting Guide, Model R-100, Microzone Electrophoresis System, September 1972
5. Beckman Instructions 015-083601-A, Model R-111, Microzone Digital Integrator, December 1972
6. Beckman Instructions, 015-083623, Model R-110, Microzone Densitometer, August 1972

2.8 FURNACE

Manufacturer: Astro Industries, Inc.

Model Number: 1000A

Cost: $4875

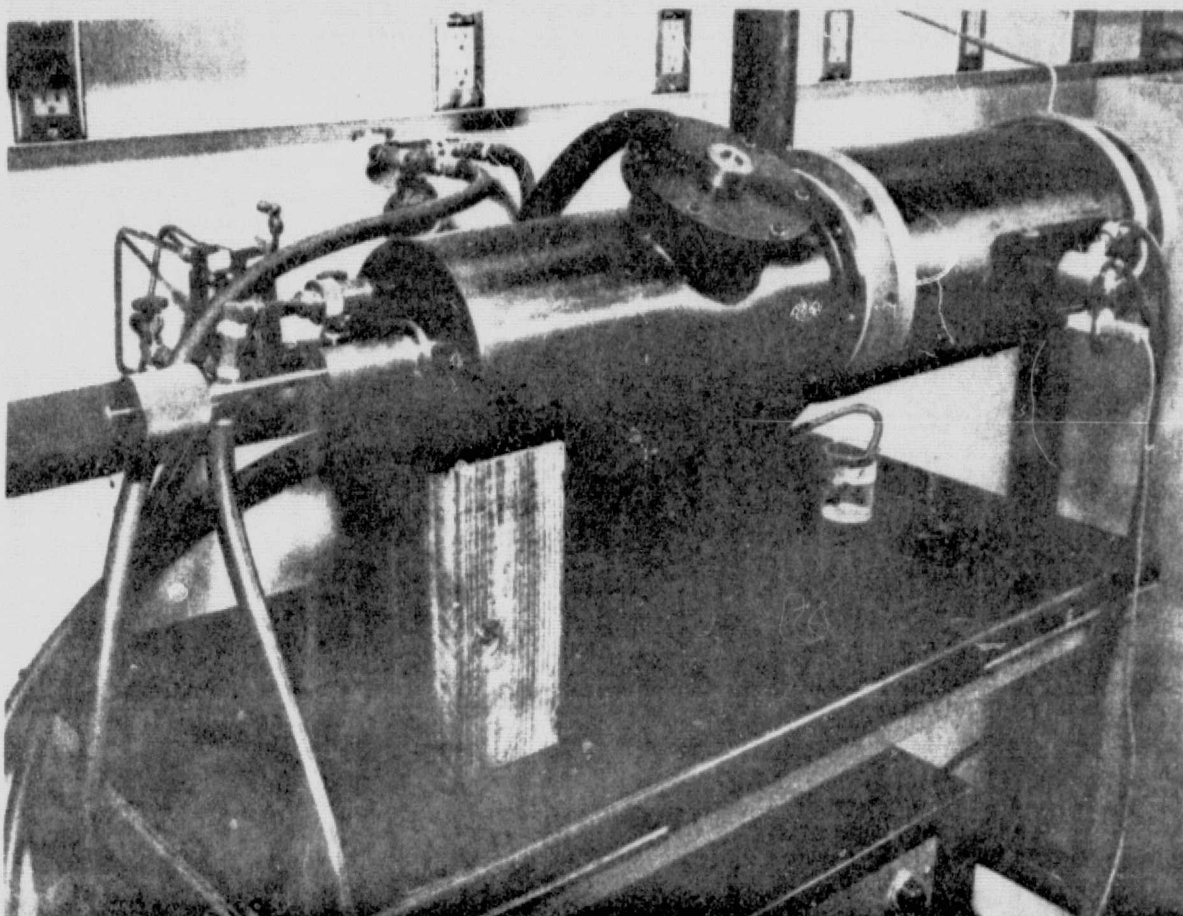

Figure 2.8-1. Astro Furnace - Model 1000A

2.8.1 Description

Applications include melting and sintering, annealing, hot pressing, crystal growing, pyrolytic deposition, thermocouple calibration, diffusion studies, thermal analysis, physical and mechanical properties testing, and use as a black body radiation source.

The 1C00A is capable of sustained operation at 3000 C in inert or reducing atmospheres; and, with the addition of appropriate accessories, 1840 C in an oxidizing atmosphere, 2300 C with typical operating vacuums below 10^{-1} torr, and 2000 C below 10^{-3} torr. Heat up-time from ambient to 3000 C is 30 minutes or less.

The chamber has straight-through access for convenient loading from both ends. Two diametrically opposed radial ports at the midpoint and one top axial port are standard. One radial port has a 5/8-inch-diameter sight window equipped with an anti-fog diffuser. The other two ports are plugged. Optional thermocouples, sight windows, and feedthrough adapters can be installed in place of plugs.

The 12 KVA power supply includes a stepdown load transformer and silicon controlled rectifier power regulator. Power is manually adjustable from 0 to 100 percent by means of a panel-mounted potentiometer. A front panel plug will accept output from an external automatic temperature controller. Maximum power output requires 5 ma dc input, into 1500 ohms. Temperature sensors, automatic temperature control, programming, and recording accessories are available, and described in the appropriate data sheets.

2.8.2 Performance Characteristics

Temperature

3000 C in inert or reducing atmospheres
1840 C in an oxidizing atmosphere
2350 C in 10^{-1} torr vacuum
2000 C in 10^{-3} torr vacuum

Hot Zone Dimensions

2.44 in. dia. x 6 in. long (6.2 x 15.2 cm)

Uniform Temperature Zone

2 in. long (5.1 cm)
1500 to 2400 C $\pm$ 5 C

Power Adjustable

0 to 100 percent

2.8.3 Physical Characteristics

Furnaces: 14 in. o.d. x 20 in. high (35.6 x 51 cm)

Muffle Tube: 10 in. o.d. x 18 in. long (25.4 x 46 cm)

Assembly Weight: 130 pounds (59 kg)

2.8.4 Suitability Analysis

	Disposition: Accept	Disposition: Verify	Disposition: Unaccept
CONSTRUCTION. The shell is cast aluminum with an anodized exterior. Bulkheads are nickel-plated aluminum. Integral water passages in the shell and bulkheads maintain surface temperatures at 60 C or less at maximum sustained operating temperatures. There are no water-wetted welds or brazed joints in the furnace interior. The vessel is manufactured in accordance with ASME Boiler and Pressure Code Requirements, and is provided with shunt trip main power breaker and water flow safety interlocks. Pressure capabilities are from vacuum to 15 psig positive pressure. The unit must be floor- or bench-mounted.			
MATERIALS			
Aluminum			
Nickel			
Viton, O-rings			
Silicone, O-rings, washers			
Stainless steel			
Graphire heating element			
Quartz window			
Alumina hearth			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Rugged construction			
Heater element and sleeve could pose loose fit		X	
Push rod requires caging			
ELECTRICAL POWER			
208/230 vac, 60 Hz, single phase, 12 kva			X
SUSCEPTIBILITY AND RADIATION			
Leads are potential EMI source, especially when on-off switching. The SCR rectifiers in the power supply would be an EMI source if used.			X
CONTAMINATION GENERATION			
Alumina		X	
ATMOSPHERE			
0 to 15 psia	X		

	Disposition		
	Accept	Verify	Unaccept
EQUIPMENT COOLING			
2.5 gpm water at 50 psi differential, 65 to 85 F		X	
Power leads are water cooled			X
Surface temperature <140 F (60 C)			X
ZERO-G EFFECTS			
Furnance is not gravity-dependent	X		
Specimen containment excluded from evaluation		X	
OPERABILITY			
Guards required to protect from sharp corners and hot surfaces			X

2.8.5 Modifications

Note: This furnace is configured without the power supply or control unit, but with the optional quench chamber and muffle tube assembly.

9-G Mounting

1. Rework swivel mount to a stationary condition. Secure with clamp and bracket assemblies in three places; see Figure 2.8-2. Pushrod to be oriented to floor; access port of quench chamber to be oriented toward operator at approximately eye-level. For pushrod movement allow 15 inches minimum.

2. Replace brass knob of pushrod with one of aluminum and add positive-lock clamp to secure rod when not in use.

3. Provide locking features for three knurled upper muffle hearth bolts.

4. Provide mesh cover to prevent touching of hot surface.

Shock and Vibration

1. Modify coolant and power lines per Figure 2.8-3.

2. Replace structural fasteners with positive locking feature hardware.

3. Replace existing gas input line junction with vibration-proof hardware.

4. Provide interior shockmounts for hard-mounting Spacelab.

2.8.6 Cost Analysis

Modification

Basic Cost		$5,597
Modification Cost		
Fabrication	$ 1,216	
Engineering	11,206	
Test	4,416	
Documentation	2,160	
Program Management	950	
Total Modification Cost		$19,948
Total Cost		$25,545

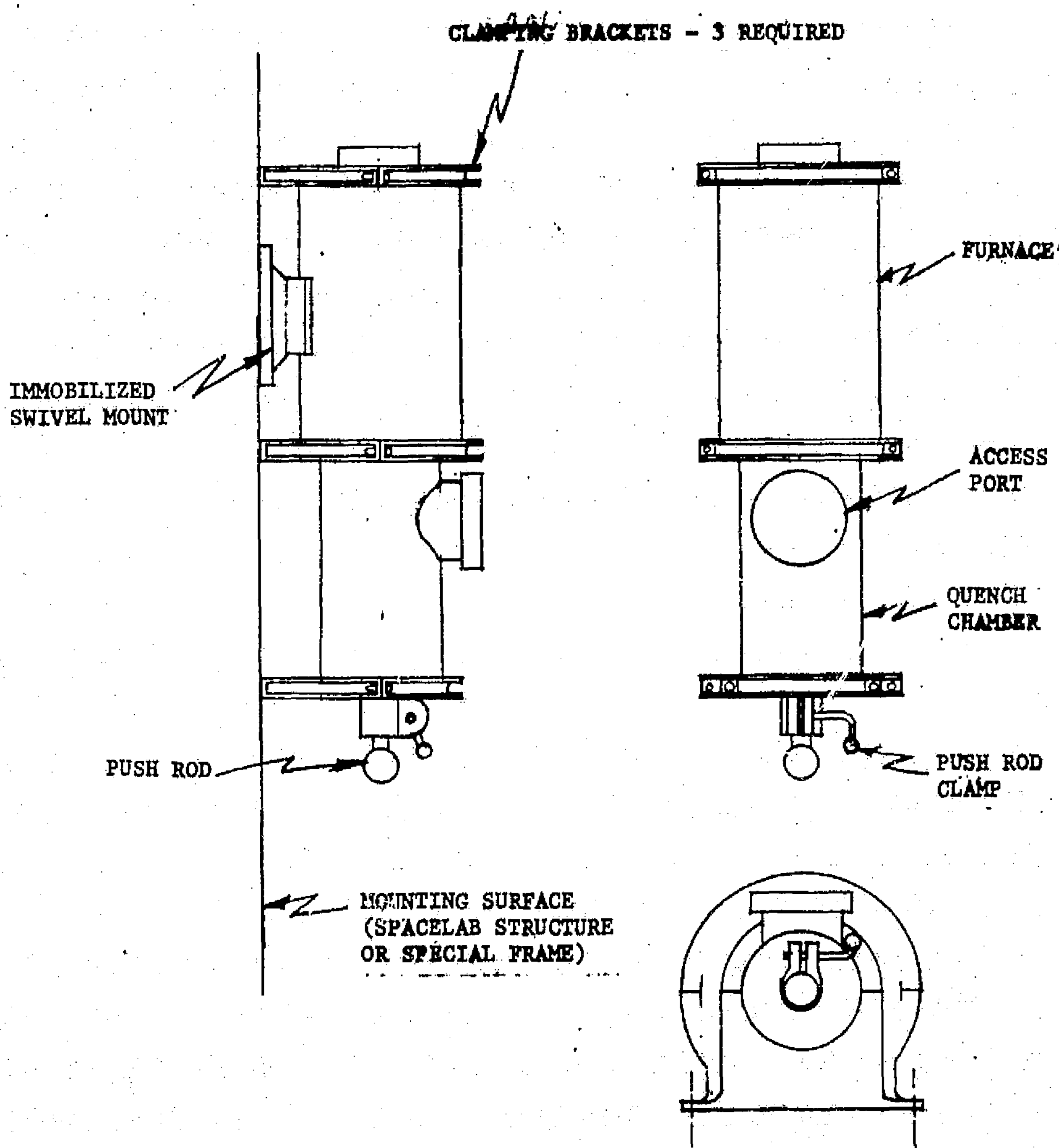

Figure 2.8-2. Mounting Configuration - Furnace - Astro Model 1000

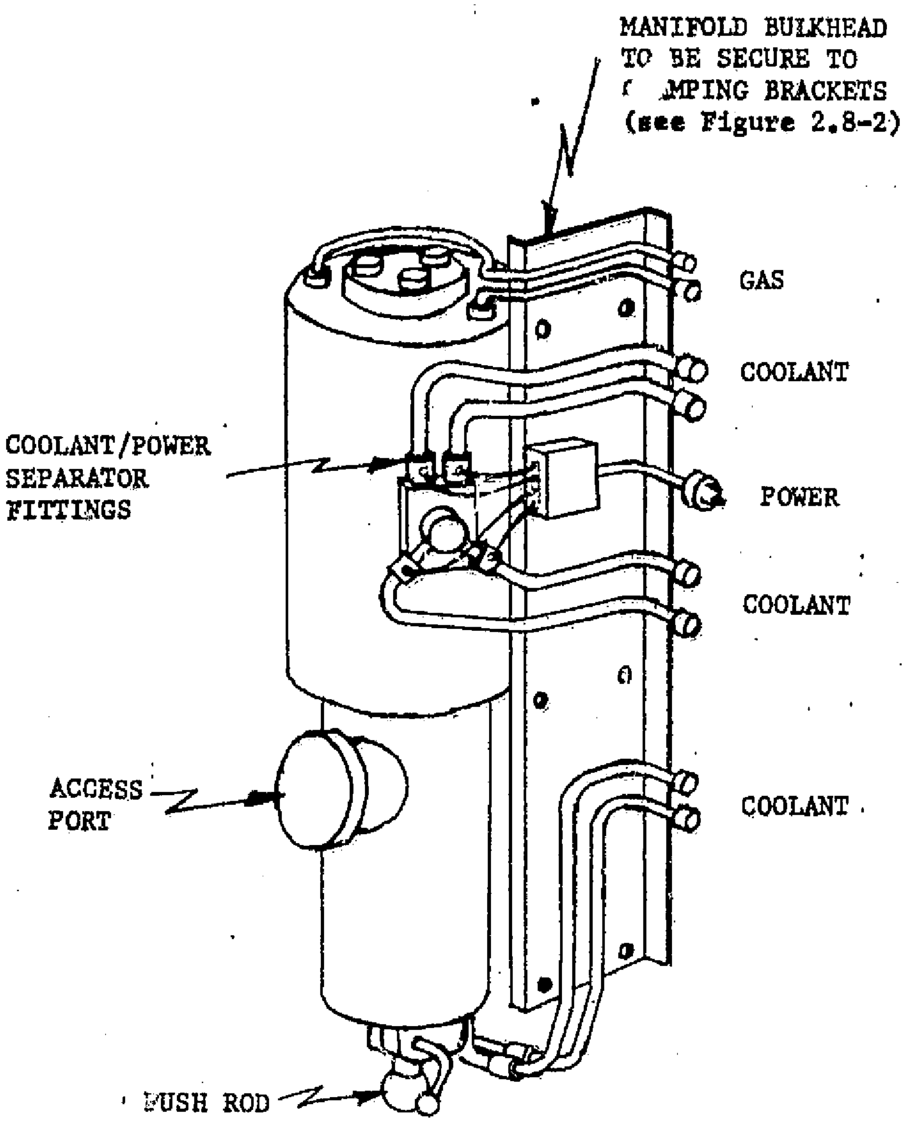

Figure 2.8-3. Coolant and Power Lines - Furnace - Astro Model 1000

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME Furnace - Astro MD 1000 NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG. TECH.	EXPD			COST $: MAT'L	LABOR	TOTAL
		Mount & Clamp Assys		2 00		25			4 00				50 00		
		Push Rod Knob		1 00		10			50				7 00		
		Lock Feature - Bolts		1 00		20			1 50						
		Mod Coolant & Power Lines				50			26 00				25 00		
		Pos Locking Hardware				50			4 00				10 00		
		Input Line Junction		4 00		1 00			4 00				100 00		
		TEST				4 00	4 00								
		SYSTEM						8 00		8 00					
		TOTAL HOURS		8 00		6 55	4 00	8 00	40 00	8 00			192 00		

Beckman INSTRUMENTS, INC.	LOT SIZE FROM	TO											MAT'L	LABOR	TOTAL
			RATE												
			O.H.												
			TOTAL										192 00	1023 60	1215 60
SHEET 1 OF 1 BY ______			TOTAL												
			TOTAL												

Space Division
Rockwell International

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New Development

Cost	$453,000
Weight	100 pounds
Complexity	.20
State-Of-The-Art Factor .	3
Data Source	Space Station Exp. 5.16

2.8.7 EC006M Delta Modification Requirements Summary

1. Incorporate the following loose parts into item design

   -Thumbscrews and furnace cavity access cover

2. Human factors modifications are as follows

   -Add silkscreened operating instructions on housing (assume 4 controls)

3. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

2.8.8 Delta Modification Costs

Fabrication		
Engineering	$ 11,500	
Test	4,420	
Documentation	2,562	
Program Management	1,066	
Total delta modification cost		$ 19,548

2.8.9 Data Sources

1. Visual examination

2. Product Information, Model 1000A, Astro Industries, Inc., (p. 73)

3. Operating and Maintenance Instructions, Astro Tubular Furnace, Astro Industries, Inc.

2.9 GAS CHROMATOGRAPH

Manufacturer: Beckman Instruments
Model Number: 6700
Cost: $8,000

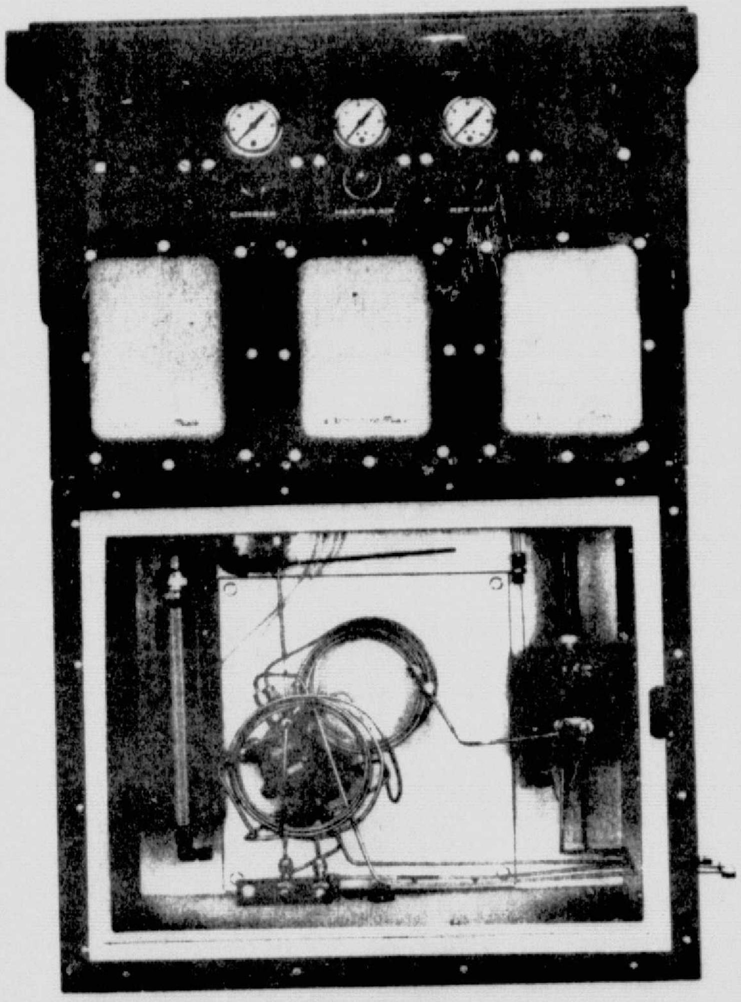


Figure 2.9-1. Beckman Gas Chromatograph

2.9.1 Description

Analyzer Unit

The Model 6700 analyzer unit is designed for field location in hazardous areas. It contains the chromatographic columns, detector system, sample inject valve, and column switching valves, all located in a temperature-controlled housing. Also included in the analyzer are the electronics which are housed in explosion-proof condulets and the flow control system for supporting gases.

The analyzer may be provided with a thermal conductivity, a hydrogen flame ionization, or a helium ionization detector. The hydrogen flame ionization detector is not recommended for Spacelab use because of the hazardous nature of gaseous hydrogen.

A full proportional temperature control system maintains stable operating temperature--within ±0.05 C--in the rapid equilibration air bath oven throughout a range of 55 C to 225 C. Control is achieved by a fast-response platinum temperature sensing probe, a 1500-watt heater, and a proportional control system which regulates power to the heater elements. A safety system is employed which removes power to the heater if plant air pressure fails, thus preventing overheating in the event of a loss of plant air pressure.

Programmer Unit

The Model 6700 Programmer includes all circuits necessary for measuring the detector signal, automatic control of all time-related functions and data reduction and presentation. The programmer is shown in Figure 2.9-2.

Operator controls and indicators permit simple operation and calibration. An integral test meter with selector switch and light emitting diode indicators permit monitoring of system operation and rapid testing of all major circuits for malfunction isolation.

2.9.2 Performance Characteristics

Sensitivity:	1 to 5 ppm full scale (Helium Detector)
Capability:	Trace analysis for inorganics and hydrocarbons
Air Requirements:	2 to 5 cfm at 30 psig
Carrier Gas Requirements:	50 to 100 cc/min normal, varies with application
Sample Flow:	Approximately 10 cc/min liquid or 100 cc/min vapor through analyzer (bypass as required)
Operating Temperature:	55 to 225 C as required
Temperature Control:	±0.05 C

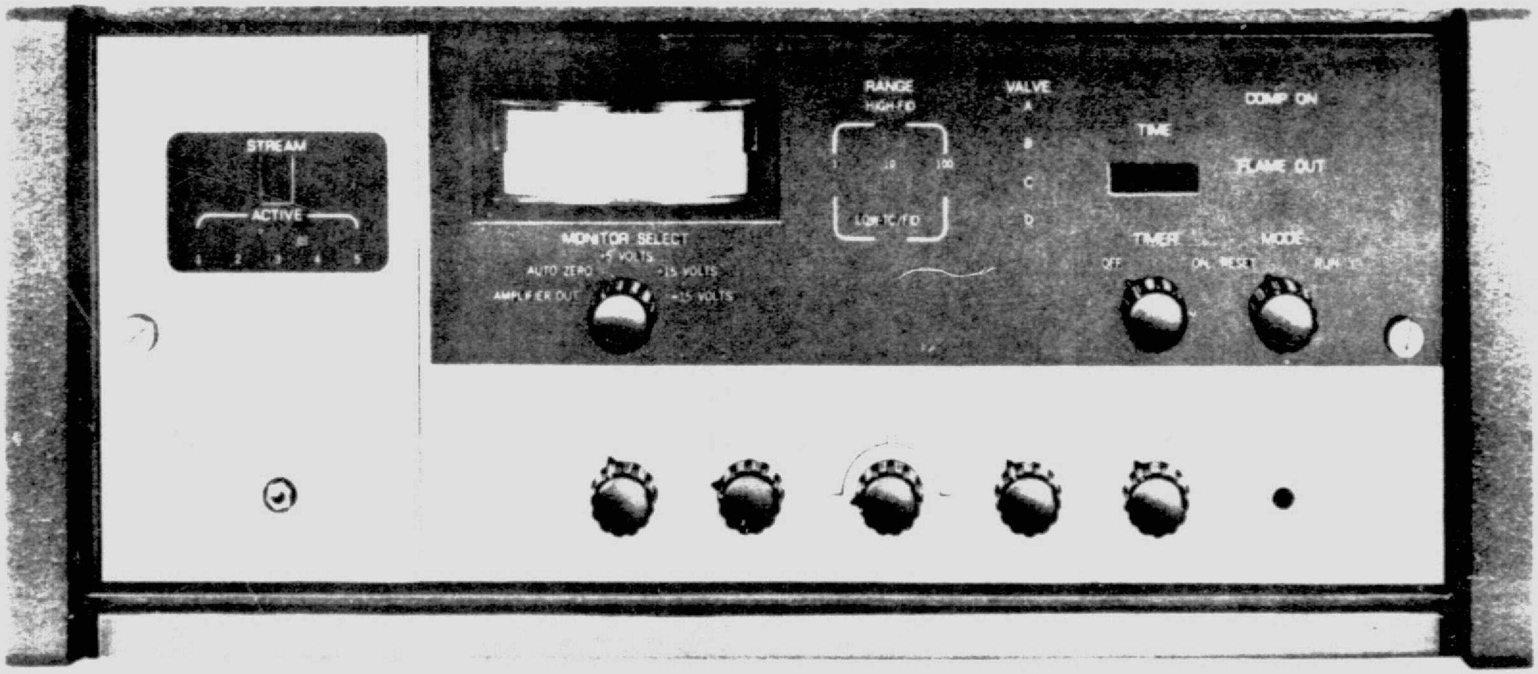


Figure 2.9-2. Gas Chromatograph Programmer Unit

Safety: Designed in accordance with requirements of the Occupational Safety and Health Act (OSHA).

Designed in accordance with CSA requirements (applied for and pending).

2.9.3 Physical Characteristics

Analyzer

Dimensions: 36.5 in. (92.7 cm) high
22 in. (55.9 cm) wide
12.12 in. (30.8 cm) deep

Weight: 175 lb (79.3 kg) net

Programmer

Dimensions: 7 in. (17.9 cm) high
19 in. (48.3 cm) wide
25 in. (63.5 cm) deep

Weight: 70 lb (31.7 kg) net

2.9.4 Suitability Analysis

CONSTRUCTION. Analyzer is extremely rugged. Control electronics are mounted on 1/2-inch-thick aluminum. Electronics have explosion-proof containment. Unit is floor mounted. One-eighth-inch tubing is coiled inside insulated oven. Fittings are building trade type. The analyzer is bench mounted.

The programmer consists of a drawer of electronics contained in a sheet-metal housing. Circuit boards are mounted on edge and supported on the bottom and sides. The programmer is rack mounted.

	Disposition: Accept	Verify	Unaccept
MATERIALS			
Teflon-insulated wire Asbestos insulation Fiberglass circuit boards Knobs and PCB board frames are plastic Glass meter faces			
SHOCK			
Both units require special mounting to floor or rack to survive 9-g landing load.	X		
Oven door latch may not withstand shock environment.		X	
VIBRATION			
Tubing analyzed not tied down			X
Sampling control valve not securely mounted			X
Screws and bolts do not have positive retention			X
Circuit boards are large, rattle in fixture and have components which could back out; see Figure 2.9-3.			X
ELECTRICAL POWER			
Power Form: 107 to 127 v ac 50/60 Hz	X		
Dissipation: Analyzer 1500 watts			X
Programmer 250 watts	X		
ELECTRIC SHOCK			
Designed for Class 1, Group D (and Group C, ethylene), Division 1 requirements of NEC. U.L. approval pending.	X		

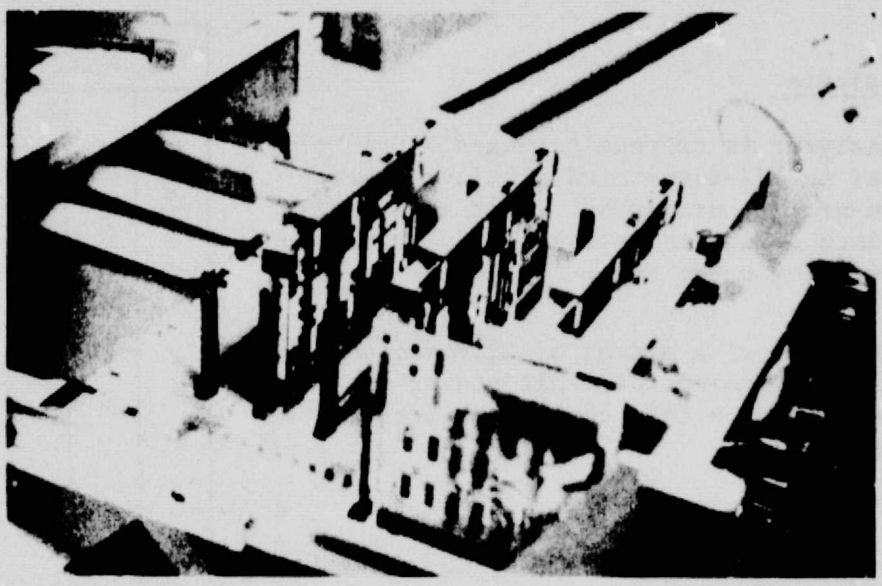


Figure 2.9-3. Programmer Circuit Board Installation

	Disposition		
	Accept	Verify	Unaccept
DATA MANAGEMENT COMPATIBILITY			
Direct computer compatibility via priority interupt or long-term memory	X		
Detector signal to programmer, 0 to 1 volt			
MAINTAINABILITY			
Programmer has built-in indicators showing failures of circuitry (Figure 2.9-4)	X		

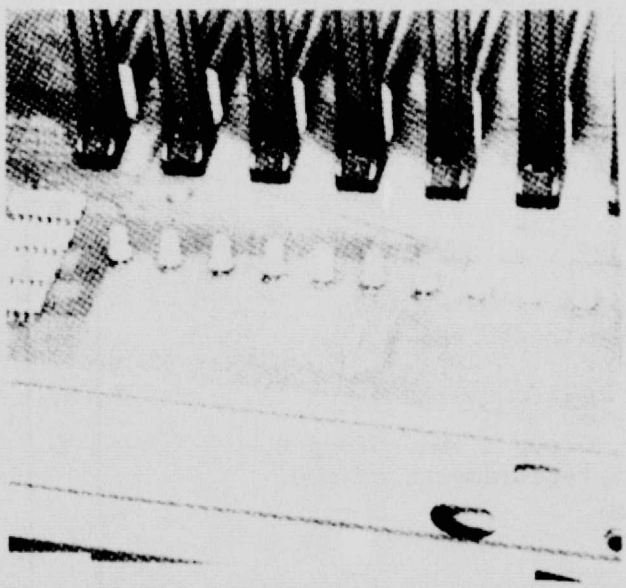


Figure 2.9-4. Failure Indicator Lights

	Disposition		
	Accept	Verify	Unaccept
EMI SUSCEPTIBILITY AND RADIATION			
Screw-down wire terminal strips in programmer input/output in place of connectors. See Figure 2.9-5.			X

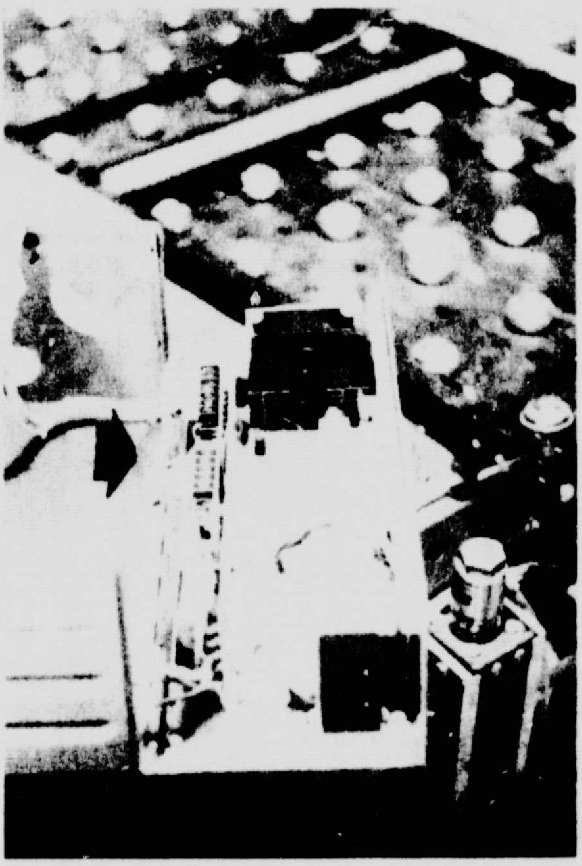


Figure 2.9-5. Screw-Type Terminal Strip

	Disposition		
	Accept	Verify	Unaccept
NOISE GENERATION			
Fan noise not evaluated		X	
FLAMMABILITY			
Analyzer unit is built to operate in explosive environment existing in petroleum industry; analyzer does not contain flamables.	X		
Programmer uses plastics throughout. PVC wiring insulation.			X
TOXICITY			
No prohibited toxins identified; designed to OSHA requirements.	X		
CONTAMINATION GENERATION			
Asbestos insulation around oven could flake (edges of sheets exposed).			X
Glass meter faces			X
ATMOSPHERE			
Analyzer designed to operate in explosive atmosphere; no data on humidity range; analyzer not affected by humidity.	X		
Programmer does not appear sensitive to humidity in habitable confines.	X		
AMBIENT TEMPERATURES			
Analyzer: -20 to -120 F (-29 to 50 C)	X		
Programmer: 32 to 110 F (0 to 43.3 C)	X		
EQUIPMENT COOLING			
Programmer has internal forced air fan.	X		
Analyzer has oven requriing 1500-watt heater. High-power heater not required for small sample size expected on Spacelab. Estimate power reduction to 100 watts. Air flow of 2 to 5 scfm will also be reduced.			X
OPERABILITY. Units do not have protrusion protection			X

2.9.5 Modifications

2.9.5.1 Analyzer

Construction

Shatterables. Gauges, to be covered with a Lexan plate

9-G Mounting/Integrity.

1. Fabricate two mounting brackets as shown in Figure 2.9-6. Attach with Aeroflex type shock mounts.

2. Clamp miscellaneous tubing internally as shown per Figure 2.9-7.

3. All wiring to be clamped--approximately 20 cable clamps required.

4. Remove and discard existing covers and replace with covers as shown in Figure 2.9-8.

Protrusions and Edges Safety.

1. Remove door latch and replace with round-type similar to Southco Inc., Part No. 24-10-302-10. Requires door modification. See Figure 2.9-9.

2. Add molding to edges of analyzer.

Shock-Vibration-Acceleration-Acoustics Resistance. Fragility of the thermal conductivity bridges filaments requires that this unit be stored in a vibration isolated enclosure. See Figure 2.9-10.

Depressurization Hazard Suppression. The sudden depressurization could ruin the instruments columns. (The devices that separate the sample). No hazard will arise as a result of this. Drill relief holes (2) in pressure guage rear shell.

Materials Usage

Flaking and Peeling Resistance. Remove oven insulation (marenite) and coat with polyimide varnish to prevent flaking.

Concentrations of Flammable/Unident. Materials. Replace all plastic control knobs with metal (4 knobs).

Non-Prevalent Commercial Materials (or Warnings on Handling/Usage of Items.

1. All fasteners will be changed to Cres or a nylock design (est. 120 fasteners).

2. All cadmium parts (sheet metal, etc.) to be disassembled and stripped and nickel plated. (4 brackets)

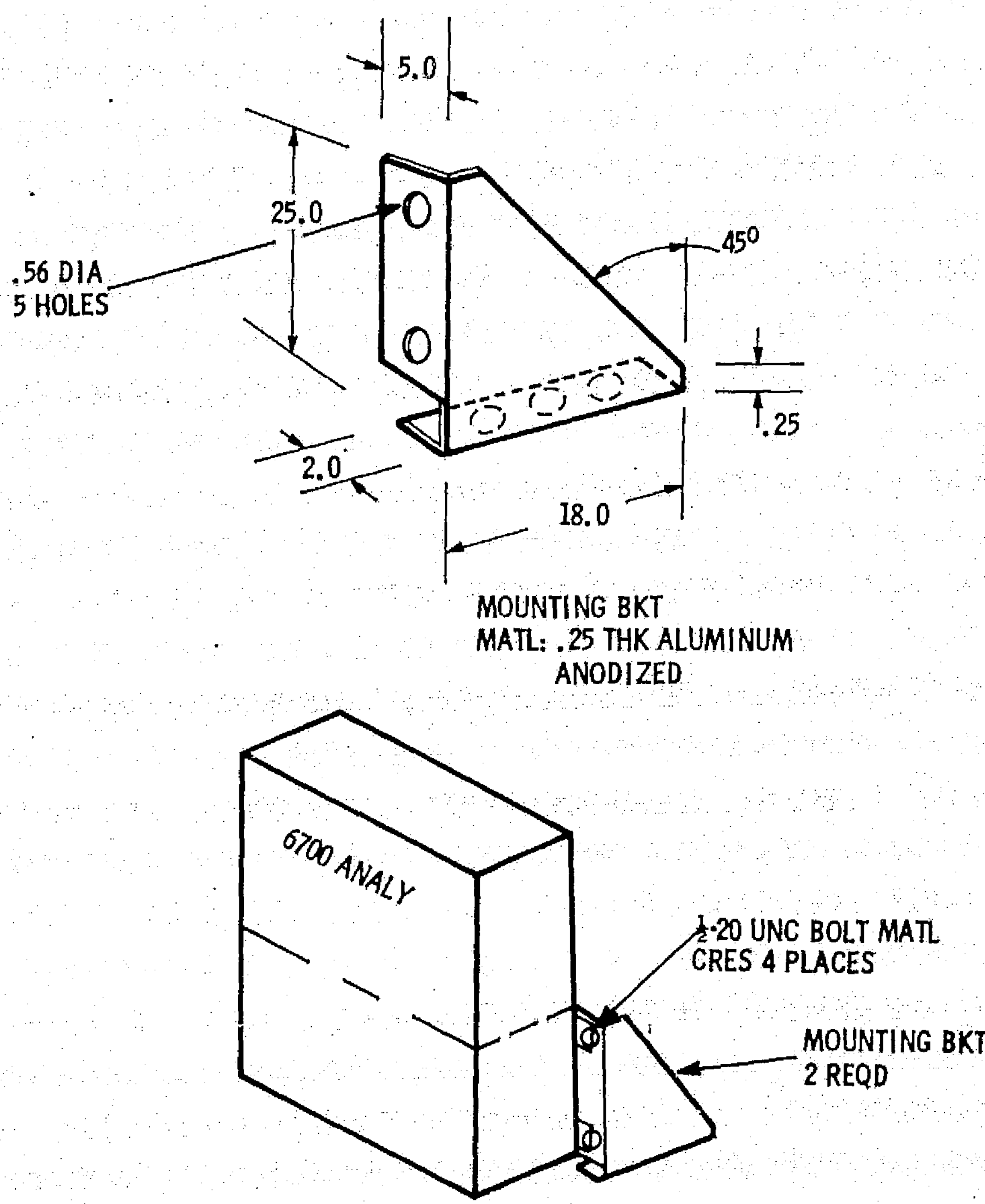
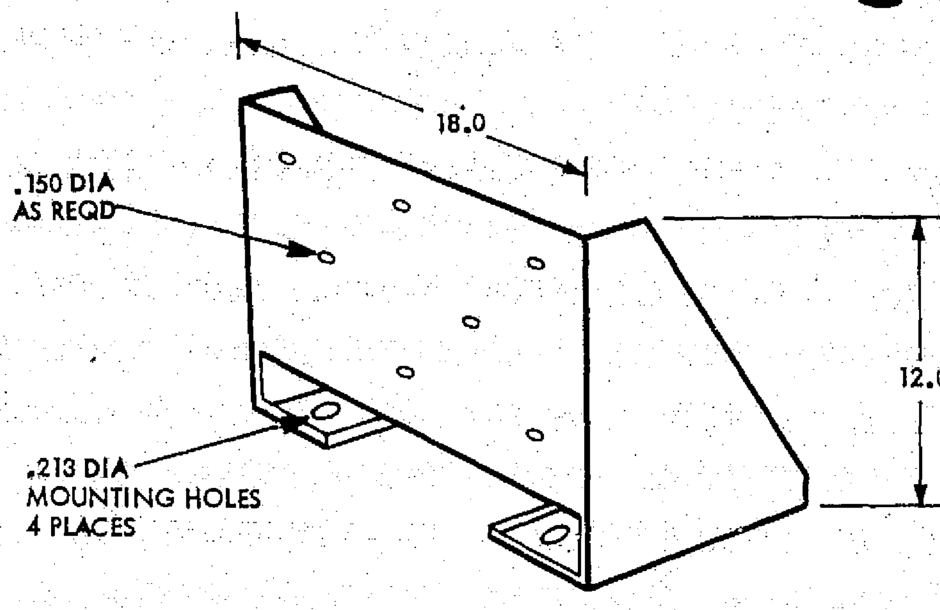
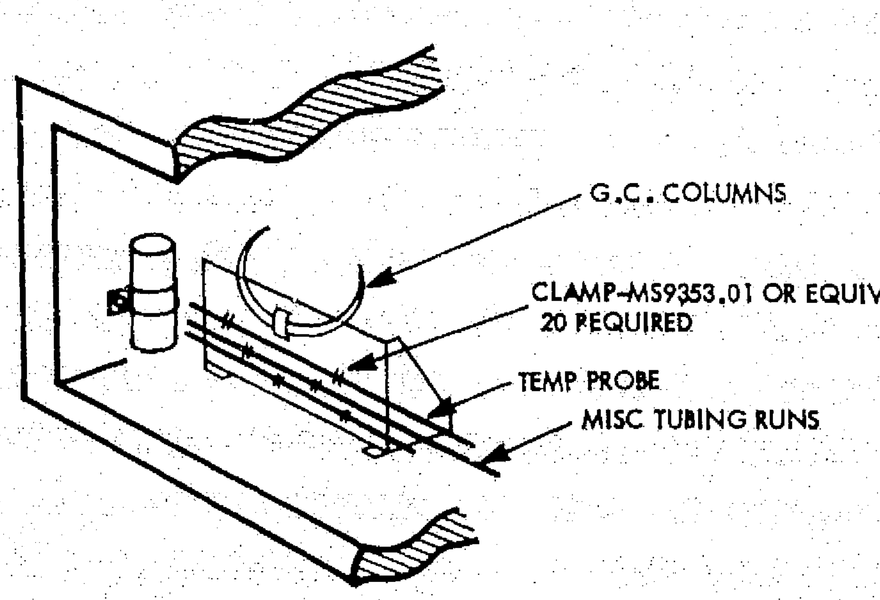


Figure 2.9-6. Analyzer Mounting Brackets



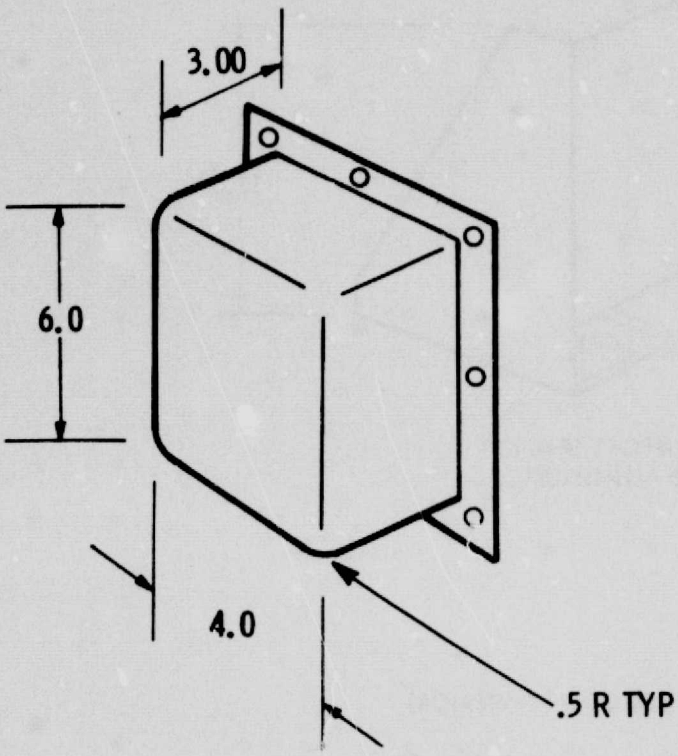
TUBING SUPPORT BRACKET
MATL: .06 ALUMINUM

6700 ANALYZER OVEN (INTERIOR)



(TYPICAL SUPPORT FOR TUBING)

Figure 2.9-7. Tubing Support Bracket



VALVE & VALVE DRIVER COVER
3 REQD-MATL: .04 CRS
NICKLE PLATED

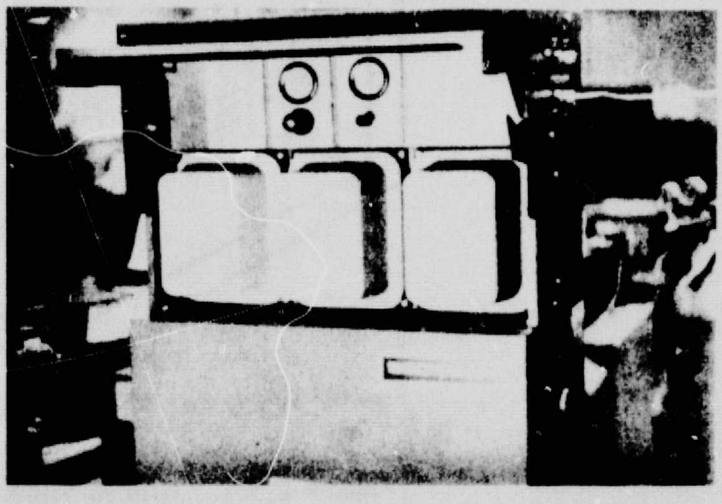


Figure 2.9-8. Electronics Covers

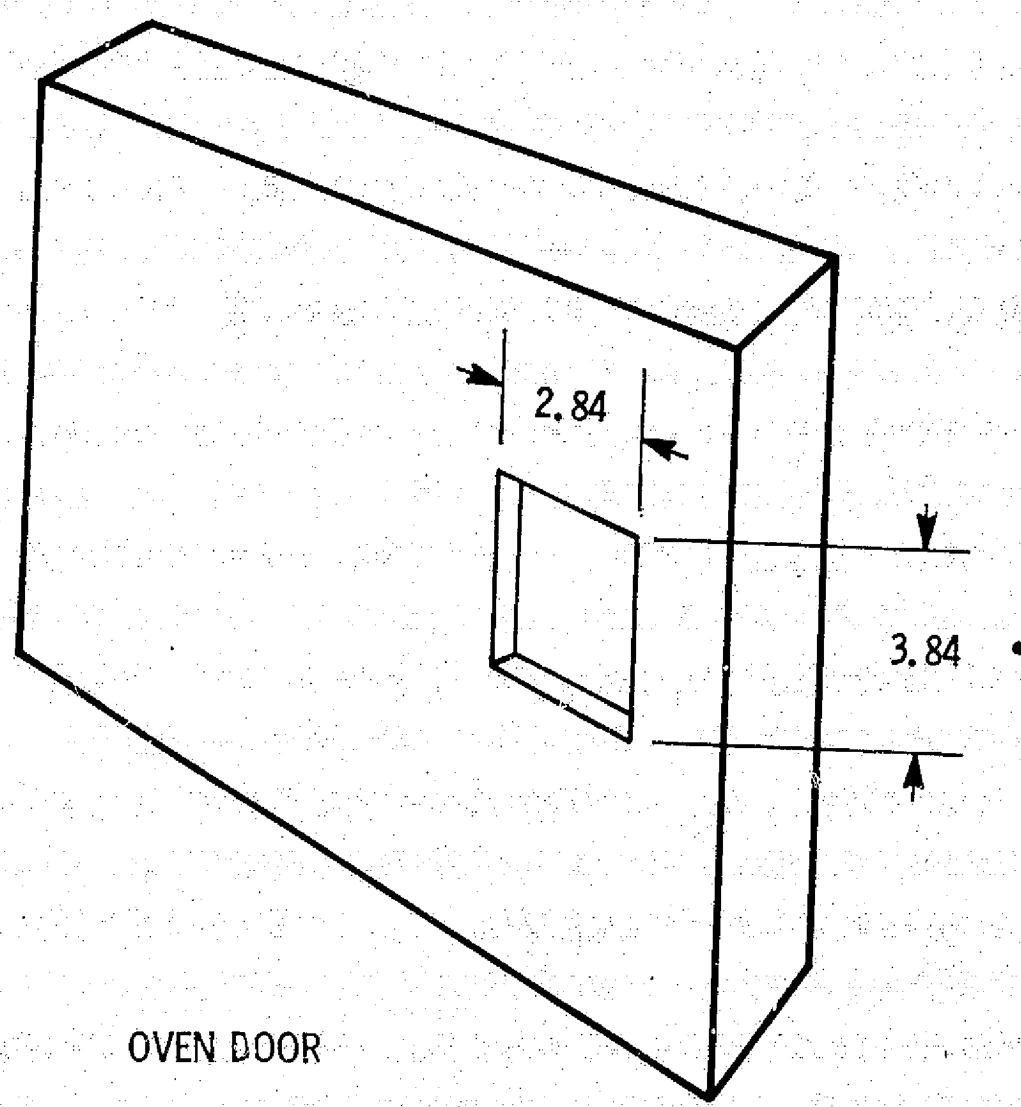
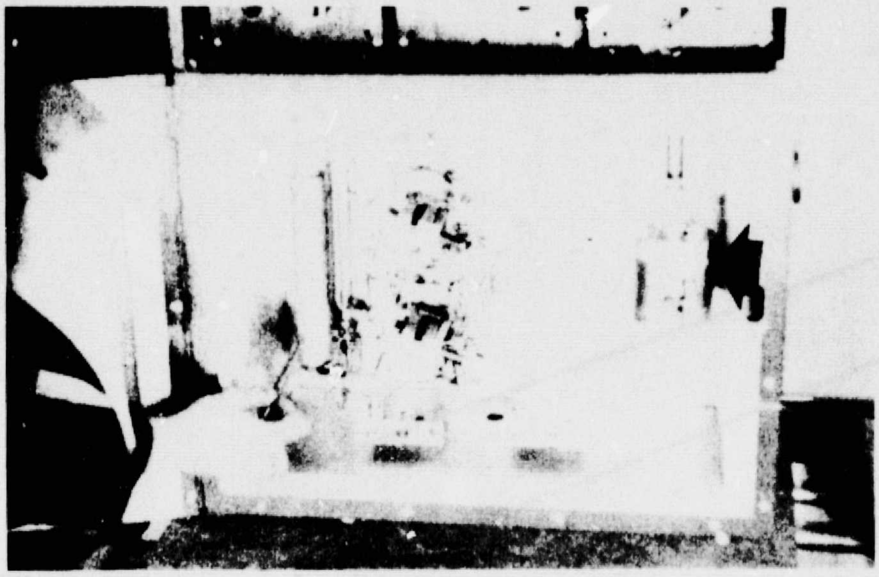


Figure 2.9-9. Door Modification



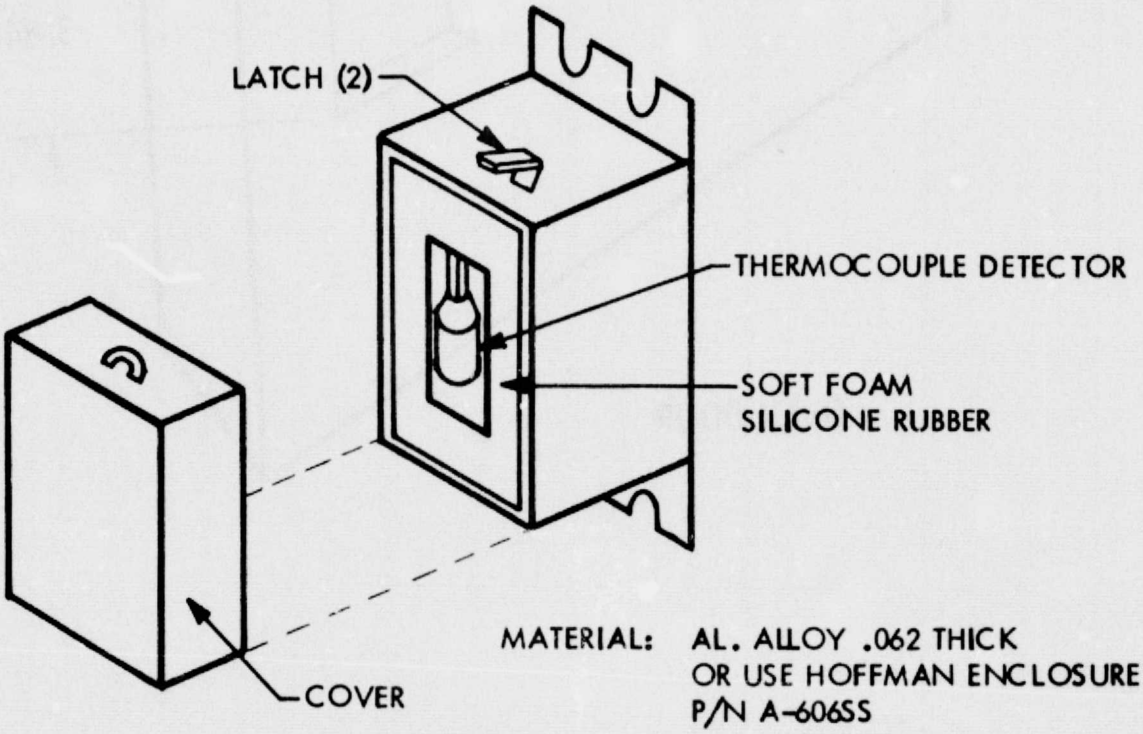


Figure 2.9-10. T/C Bridge Storage Container

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Atmosphere Contamination Compatibility

The gas chromatograph will be venting to atmosphere its carrier gas (He) and heated compressed air from oven and valve operation. Requires overboard vent.

2.9.5.2 Programmer

Construction

9-G Mounting/Integrity. (Instrument weight 70 pounds net)

1. Add printed circuit retention device. Fabricate from 0.08 thick aluminum, anodized. See Figure 2.9-11.

2. Conformal coat 20 printed circuit boards (including mother board).

3. Remove existing wiring (including ribbon wiring) and replace with TFE insulated wire. See Operating Manual for Schematic.

4. Support mother board per Figure 2.9-12.

5. Conformal coat 2 transformers in power supply section

6. Pin knobs to shaft.

Protrusions and Edges Safety. Bezel to be added to equipment rack. (1.00 00, x 0.031 wall aluminum tubing)

19-Inch Rack Mount Capability. Programmer is mountable in a standard 19-inch rack utilizing the chassis supports described in Figure 2.9-13.

Shock-Vibration-Acceleration-Acoustics Resistance. Conformal coat and secure printer circuit boards. Tie down approximately 6 capacitors in power supply section that are mounted on terminal strip.

Materials Usage

Flaking and Peeling Resistance. Front panel and outside of chassis to be painted with a clear approved paint.

Concentrations of Flammable/Unident. Materials.

1. Replace plastic control knobs with metal (8 places).

2. Conformal coat transformer.

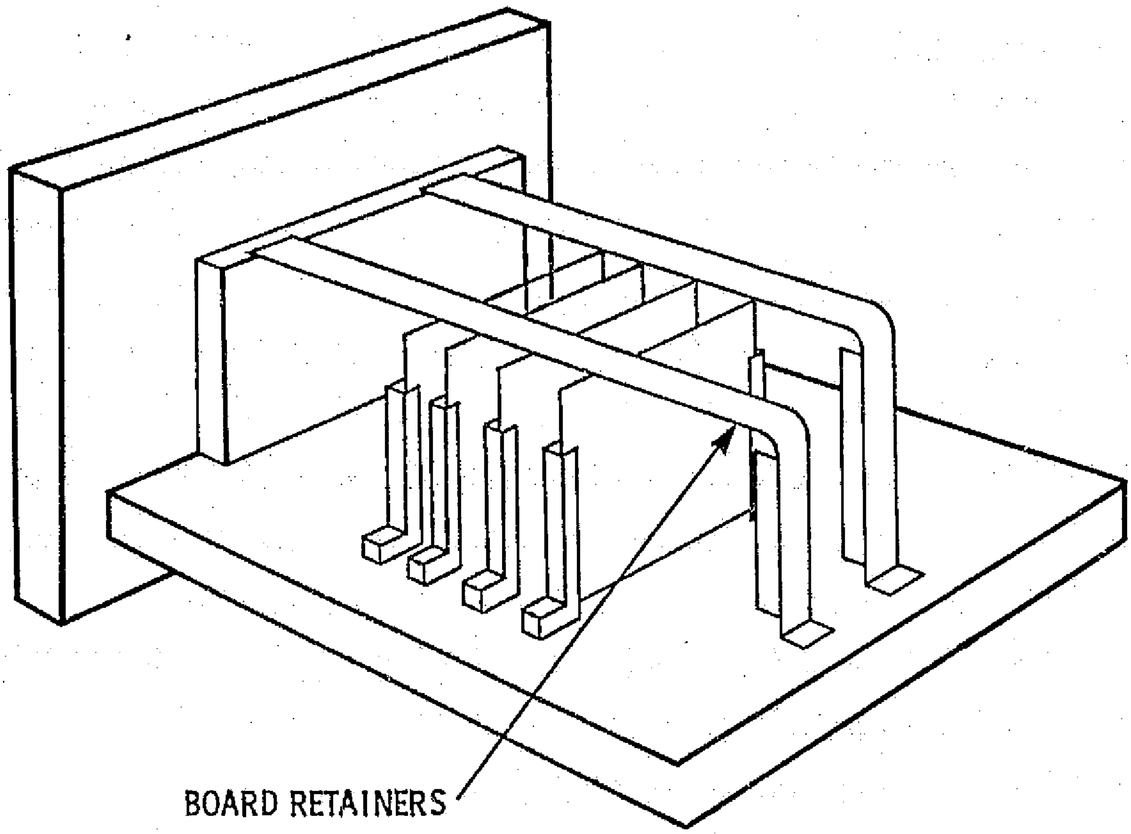

Figure 2.9-11. Printed Circuit Board Retention

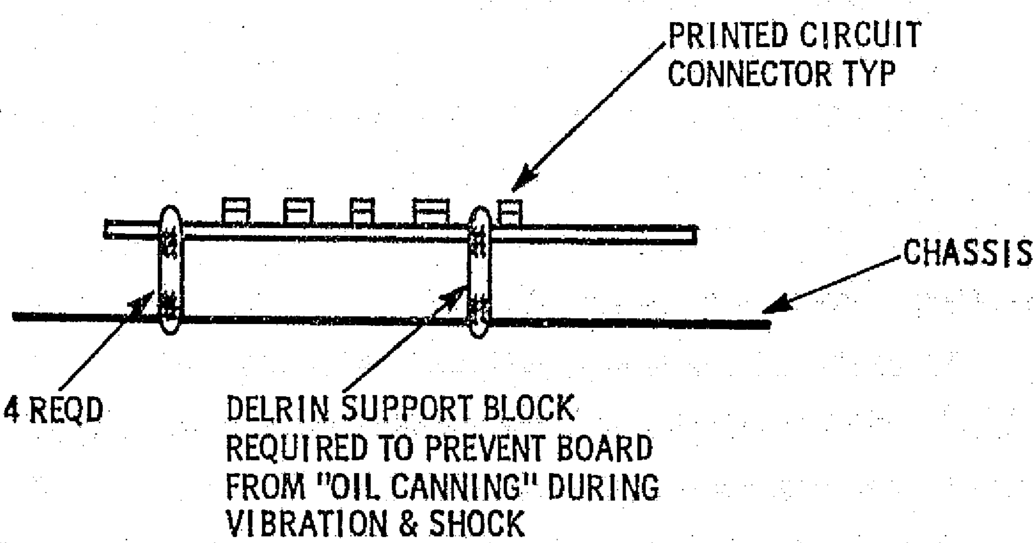

Figure 2.9-12. Mother Board Support

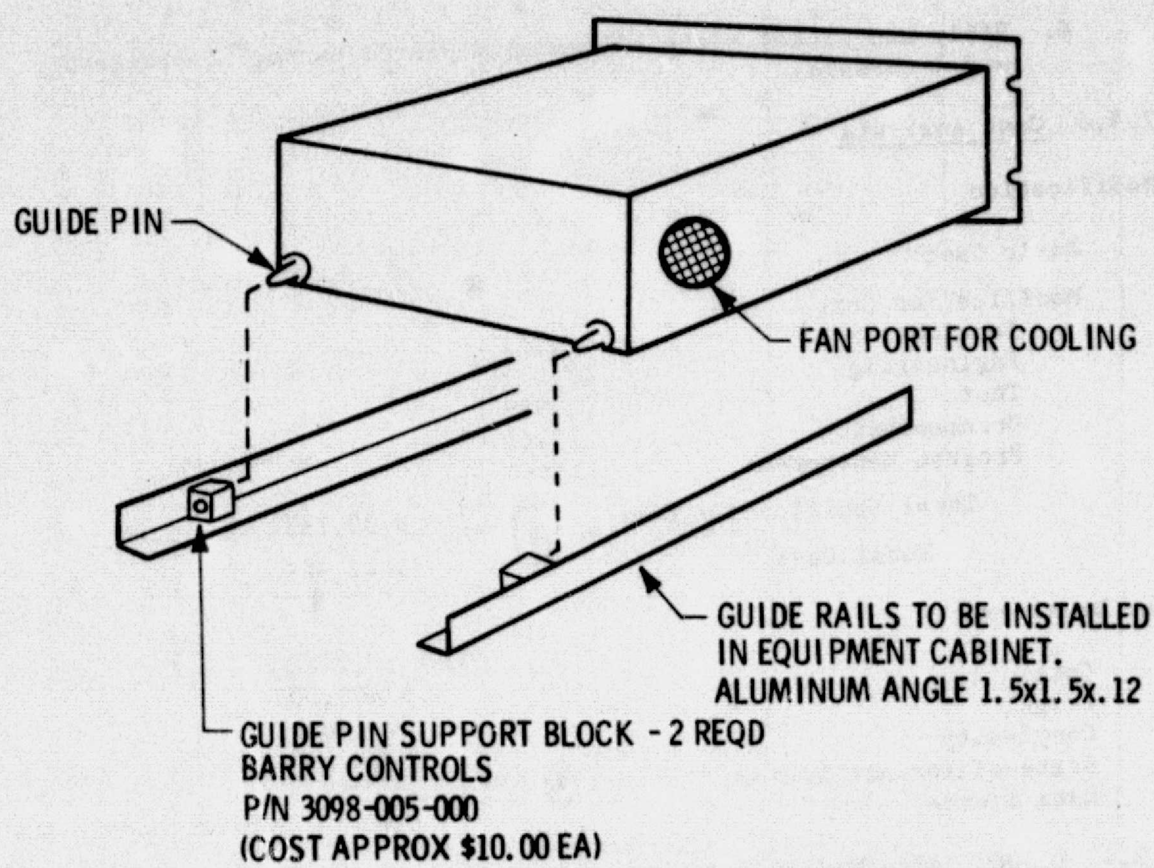

Figure 2.9-13. Programmer Rack Mounting

Non-Prevalent Commercial Materials (or Warnings on handling/usage of item).

1. Replace all fasteners with a NYLOCK, Cres type (est. 50 fasteners).
2. Paint front panel and chassis with a clear approved paint.
3. Wire change to TFE.
4. Strip and nickel plate all cadmium plated parts. 2 brackets and 2 chassis.

2.9.6 Cost Analysis

Modification

Basic Cost		$ 9,185
Modification Cost		
Fabrication	$ 8,163	
Engineering	17,811	
Test	5,988	
Documentation	2,160	
Program Management	1,661	
Total Modification Cost		$ 35,783
Total Cost		$ 44,968

New Development

Cost	$ 400,000
Weight	30 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Command Service Module ECS

2.9.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and delta thermal range capability
   a. Provide chambers and test time for acceptance and qual
   b. Respecify and replace 180 electronic parts for vacuum and thermal (currently has inadequate thermal range testing)
   c. Replace lubricant in programmer fan
2. Provide connector interface for items testing (for analyzer only) (programmer has BITE to isolate to removable assembly)
   a. Add 15-pin connector at external interface
   b. Add 15-wire test harness to 3 sealed boxes

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. Mod. 6700 Programer ASSEMBLY NAME Beckman Gas Chromatograph NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD			MAT'L	LABOR	TOTAL
		Fab. Retention Bracket	2	3 50	50	25							13 50		
		Conformal Coat PCB's	20		25 00	4 00							60 00		
		Rewire W/TFE	150		15 00	5 00		8 00					18 50		
		Fab. Support for Mother Board	4	2 00	40	10							2 00		
		Fab. Protection Bar		2 00		20							10 00		
		Conformal Coat Trans.	2		2 50	40							8 00		
		Fab. Chassis Support		3 50	1 00	20							22 50		
		Secure Capacitors	6	1 00	1 00	25							7 50		
		Overspray Exterior				75							38 00		
		Replace Control Knobs	8		40	10							12 00		
		Replace all Fasteners	50		7 50	4 00		8 00	8 00				12 50		
		Strip & Replate w/Nickel	2+2		8 00	4 00		8 00	8 00				58 00		
		150 Hour Bakeout						8 00					250 00		
		Other				8 00	24 00	14 00	6 00	8 00					
		TOTAL HOURS		32 00	61 30	27 25	24 00	46 00	22 00	8 00					

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		TOTAL

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. Mod. 6700 - Analyzer ASSEMBLY NAME Beckman Gas Chromatograph NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.					COST $ MAT'L	LABOR	TOTAL
		Fab. Lexan Gage Plate	2	2.00	.50	.10							4.00		
		Fab. Mounting Bracket	2	2.50	.50	.20							14.50		
		Fab. Clamp	1	1.50		1.00		4.00	8.00				25.00		
		Clamp Wiring 20 Places		2.00					4.00				10.00		
		Fab. & Install Covers	3	6.00		.50			1.00				24.00		
		Replace Doorlatch	2	3.00		.50			2.00				24.00		
		Fab. & Install Molding	7	7.00	3.50	.75							21.00		
		Fab. & Install Corners	8	8.00	4.00	.50							12.00		
		Fab. T/C Bridge Storage Box	1	6.00		.50			1.00				18.00		
		Drill Relief Holes	2	.50		.05									
		Remove & Cost Insulation & Reinstall	AR			4.00			24.00				50.00		
		Replace Knobs w/Metal	4		.20	.05							6.00		
		Rewire w/TFE x	100		10.00	3.00		4.00					15.00		
		Replace all Fasteners	150		21.50	12.00		8.00	8.00				40.00		
		Stup & Nickel Plate Brackets	4			2.00			8.00				40.00		
		150 Hour Bake						8.00					250.00		
		ANALYZER TOTAL		38.50	40.20	31.15	16.00	38.00	64.00	12.00			551.00		
		PROGRAMER TOTAL		32.00	61.30	27.25	24.00	46.00	22.00	8.00			512.50		
		Update 6-5-74 1) OK													
		2) Pin Knobs	8	1.00		.15							2.50		
		3) Fab. Shock Mounts		24.00		4.00		16.00	8.00				100.00		
		TOTAL HOURS		95.50	101.50	62.55	40.00	100.00	94.00	20.00			1166.00		

Beckman INSTRUMENTS, INC.	LOT SIZE FROM	TO	RATE											
			O.H.											
			TOTAL									1166.00	5997.10	8163.10
SHEET 2 OF 2 BY STATA			TOTAL											
			TOTAL											

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c. Add three 5-pin connectors (1 for each sealed box)

d. Add 5 PCB-to-connector wires in each box

e. Add a $1/in.^2$ test signal isolation circuit board in each of 3 boxes (3 parts each)

3. Provide connector/wire junction moisture sealing (programmer only) (analyzer is explosion proof per Beckman spokesman--implying sealed interfaces)

   a. 7 PCB-to-master board (printed PCB pins)

   b. 5 molded round-pin master board to ribbon cable

   c. The SEEIR mod connectors which replaced 7 terminal strips for power supply and input/output interconnect.

4. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

5. Human factors mods

   a. Add captive 1/4 turn panel mount fasteners to programmer (4)

   b. Add silkscreen operating instructions to programmer and analyzer panels (15 controls)

   c. Replace hinge to analyzer oven access door with friction type

   d. Redesign analyzer circuit boards for ease of replacement

2.9.8 Delta Modification Costs

Fabrication	$ 971	
Engineering	23,478	
Test	5,391	
Documentation	2,562	
Program Management	1,620	
Total delta modification cost		$ 34,022

2.9.9 Data Sources

1. Visual examination

2. Analyzer and Programmer Units for the Model 6700 Process Gas Chromatograph Systems. Operating Manual. Beckman Instruments, 1973.

3. Model 6700, Process Gas Chromatograph Sales Brochure. Bulletin 4135A.

2.10 LASER

Manufacturer: Sylvania Electronics

Model Number: 948

Cost: $10,000

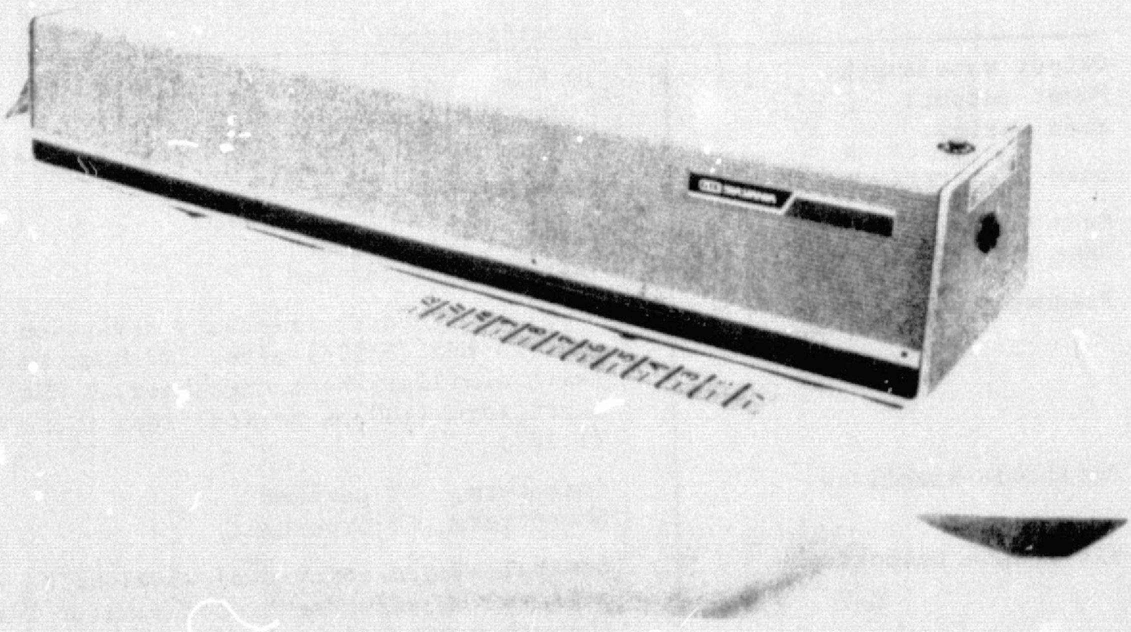


Figure 2.10-1. Sylvania CO_2 Laser

2.10.1 Description

The Model 948 was developed for, but not limited to, applications in the fields of communications and telemetry, atmospheric propagation, heterodyne studies, detector evaluation, and non-linear optics.

More than 5 watts is emitted in a TEM_{ooq} mode at a single wavelength near 10.6 microns. The output beam of the laser has a diameter of 6 mm and is linearly polarized in the vertical direction. The optical length of the laser cavity is 77 cm, short enough to ensure single-axial-mode operation. The Model 948 utilizes a 300-cm radius of curvature totally reflecting mirror mounted on a piezoelectric transducer capable of greater than $\lambda/2$ movement at 10.6 microns. The output mirror is a gallium arsenide etalon plate which acts the same as a flat mirror. Since both the inside and outside surfaces of this mirror are active reflectors, the mirror is protected in a dust enclosure. An additional output window (anti-reflection coated germanium) is used to seal the enclosure at the front of the laser.

The relatively low supply voltage for the laser tube is fed to the laser head and converted to high voltage for the tube. A dc-to-dc converter is used to set up the supply voltage to the required tube voltage. The output of the converter is highly filtered to eliminate the effects of power supply ripple on the amplitude stability of the laser output.

2.10.2 Performance Characteristics

	Specifications
Output wavelength:	10.6 microns
Power output:	5 watts (minimum)
Mode purity:	TEM_{ooq}, single frequency, single wavelength
Beam diameter:	6 mm, $\frac{1}{e^2}$ points
Beam divergence:	5 mrad, full angle
Beam polarization:	Vertically polarized
Frequency stability:	Long-term (hours) frequency deviation less than 15 MHz ($5:10^7$) after 1/2-hour warmup (with auxiliary heat exchanger, 2 MHz); short term (100 ms period) less than 30 kHz ($1:10^9$)
Amplitude stability:	Long term, <5 percent Short term, <0.5 percent
Wavelength selection:	Several single individual wavelengths can be selected by adjustment of resonator length through a piezoelectric transducer
Output frequency control:	Fine voltage control of piezoelectric transducer power supply allows continuous frequency adjustment over Doppler linewidth

2.10.3 Physical Characteristics

Size and Weight

Laser Head

6-1/2 in. x 8 in. x 36 in. (16.5 x 20.3 x 96.5 cm)
27 pounds (12.7 kg)

Power Supply

17 in. x 5-1/4 in. x 14 in. (43.2 x 13.4 x 35.6 cm)
40 pounds (18.2 kg)

2.10.4 Suitability Analysis

CONSTRUCTION. The unit has glass tubes mounted in large aluminum yokes which in turn are attached to 1/4-inch-thick aluminum base; see Figure 2.10-2. Large encapsulated power supply modules are located beside the glass tube. Power and water connections are at one end. A lens at the other end collimates the laser beam. Thin aluminum plate completely covers the laser components. The unit is bench mounted.

	Disposition: Accept	Verify	Unaccept
MATERIALS			
Glass			
Aluminum			
Silicone rubber			
Gallium arsenide etalon			
Germanium			
CO_2			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Unit has mil-type shell connectors	X		
Internal optics may be vulnerable to vibration			X
Tubing junctions with glass jackets need support			X
Components are firmly mounted external to glass tubes	X		
Lead-mounted capacitors in glass tube			X
Power supply is potted in silicone	X		
Potential realignment of optics required after vibration		X	
(Requires shockmount to solve glass tube and internal [optics, capacitors] sensitivity problems)			
ELECTRICAL POWER			
115 volts, 60 Hz at 600 volt-amps; no high voltage outside of laser head	X		
EMI SUSCEPTIBILITY AND RADIATION			
Laboratory experience indicates that unit does not generate EMI		X	
Not susceptible to EMI	X		
FLAMMABILITY			
Rubber tubing for coolant containment			X
PVC wiring in totally enclosed container	X		

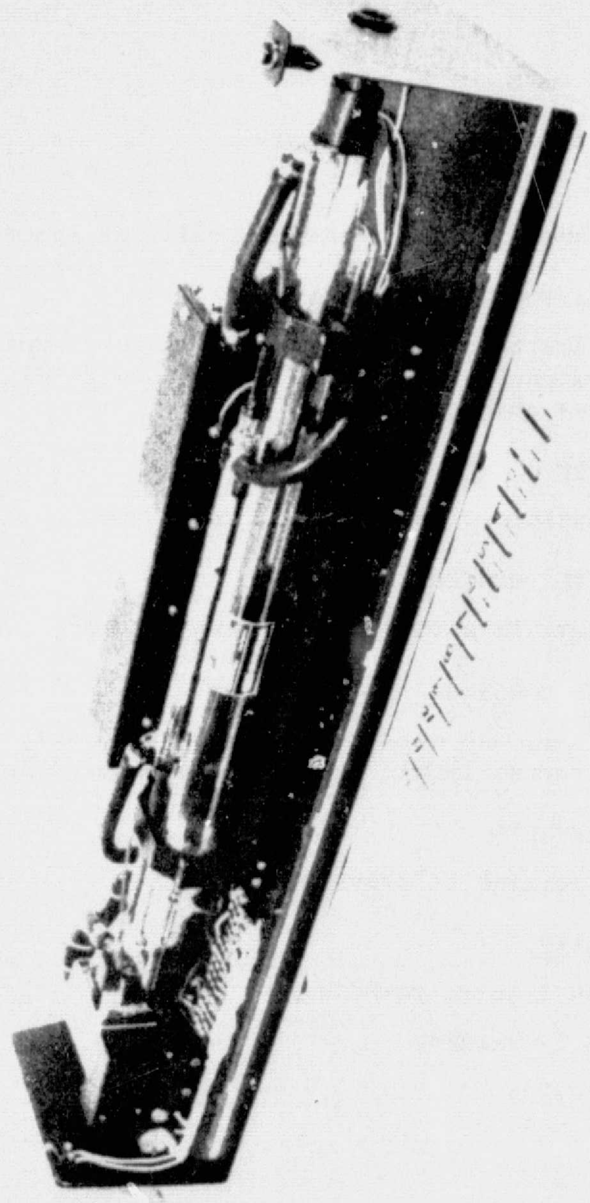


Figure 2.10-2. Sylvania CO_2 Laser Interior

	Accept	Verify	Unaccept
TOXICITY			
Electronics potted in RTV	X		
Unit is sealed			
CO_2 used in laser--amount small for Spacelab volume	X		
CONTAMINATION GENERATION			
All shatterables contained by case of unit. Laser is exception, but should be waived as microscope lenses are waived.	X		
ATMOSPHERE			
Compatible with Spacelab atmosphere	X		
AMBIENT TEMPERATURES			
Compatible with Spacelab temperatures	X		
EQUIPMENT COOLING			
Coolant, tap water (1/4 gpm); capability of Spacelab to provide liquid cooling must be verified.		X	
ZERO-G EFFECTS			
Independent of gravity	X		
OPERABILITY			
Edges require rounding			X
Beam is hazardous			X

2.10.5 Modifications

Construction

Shatterables (Laser Head). The entire laser tube is glass; therefore, shatterable. An aluminum cover provides primary protection. A cover is required over the aperture (see Figure 2.10-3). Control unit: replace meter face and indicator lights lens with Lexan windows.

9-g Mounting/Integrity (Laser Head). Secure to mounting plate - 0.5 thick aluminum clear anodize (see Figure 2.10-4). This plate and assembly will be shock mounted to work surface.

Protrusions and Edges Safety. Add 1.0 o.d x 0.06 plastic edge bumpers. Laser control unit: protrusion protection per design guidelines.

19-Inch Rack Mount Capability (Laser Head). Because of length (36.5 inches), will have to be stored or bulkhead mounted. Laser control unit will be adapted to rack mount using 0.125 thick aluminum brackets (see Figure 2.10-4).

Shock-Vibration-Acceleration-Accoustics Resistance. (Laser Head).

1. Secure wire harnesses with cable clamps; est. 5 required.

2. Provide tube clamps for water tubes; est. 5 required.

3. Replace all fasteners in both head and control unit with CRES, Nylock type; est. 150.

4. Replace all water tube clamps with screw type.

EMI Generation Suppression. Add shielded box and feed through capacitors as shown on Figures 2.10-5 and 2.10-6. Adddition of capacitors may be detrimental to unit operation and would have to be investigated; estimate 16 hours of EE time to do this. Estimated material cost $20.00.

Operating Requirements

Human Factors. Requires special instruction on handling - see "warning" (Figure 2.10-7). Install placards per figure on both laser head and control unit.

Material Control

Replace rubber tubing with braided teflon tubing. (Typical: Penn Tube Plastics Co. Braided CT-Flex.)

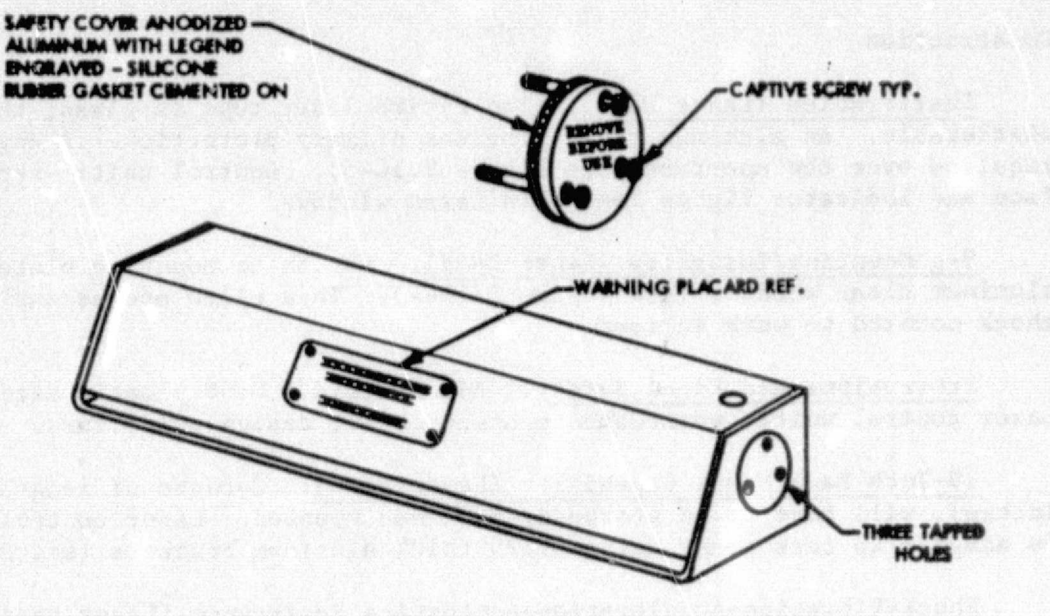


Figure 2.10-3. Aperture Safety Cover

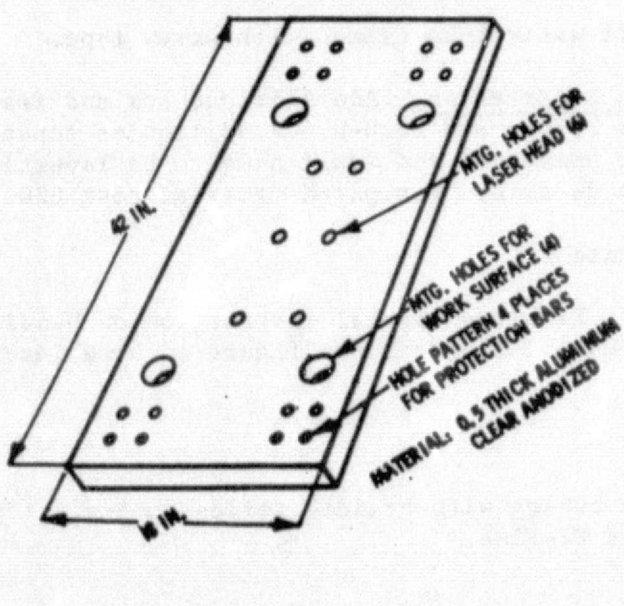
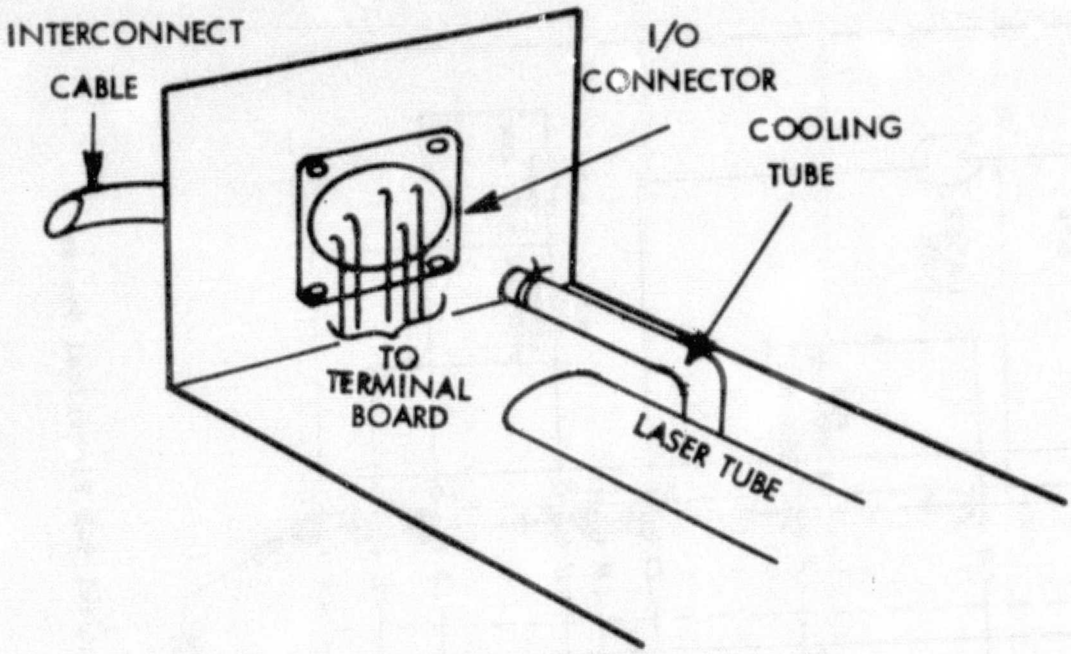


Figure 2.10-4. Laser Base



LASER HEAD PRESENT CONFIGURATION

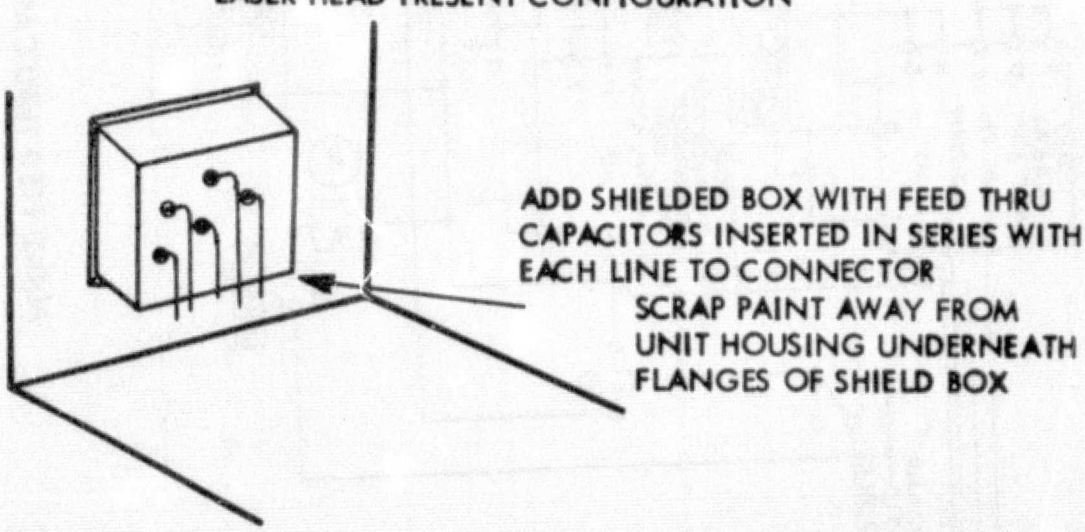


Figure 2.10-5. Laser Power Interface Modifications

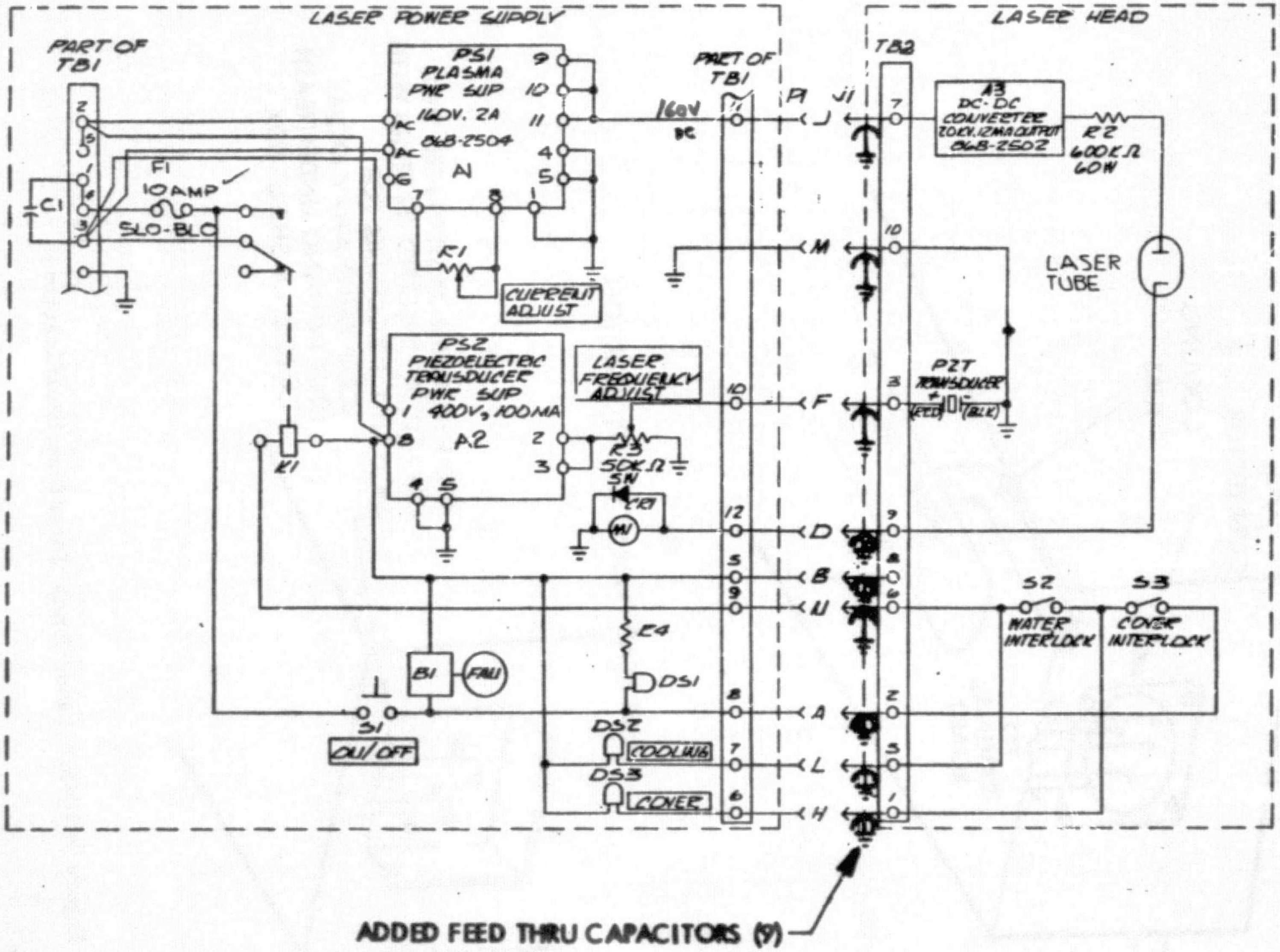


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Figure 2.10-6. Schematic Diagram - Model 948 Electrical System

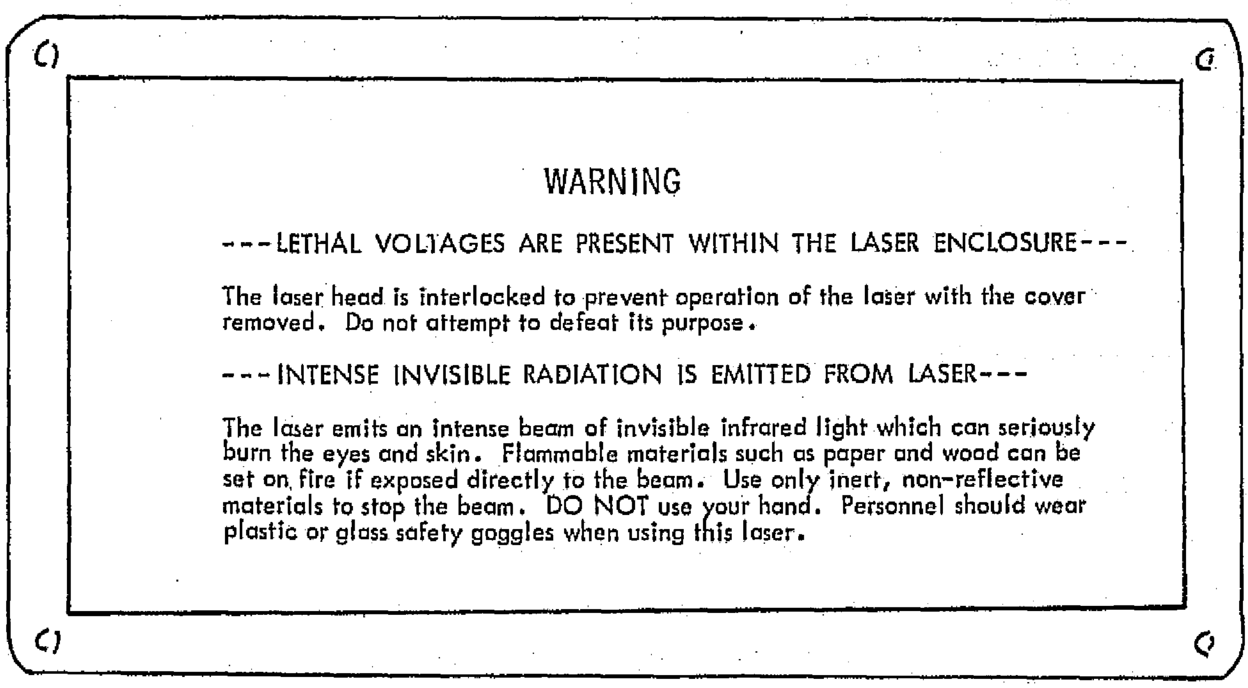

Figure 2.10-7. Warning Placard

2.10.6 Cost Analysis

Modification

Basic Cost		$ 11,481
Modification Cost		
Fabrication	$ 4,801	
Engineering	10,488	
Test	4,964	
Documentation	2,160	
Program Management	1,121	
Total Modification Cost		$ 23,534
Total Cost		$ 35,015

New Development

Cost	$171,000
Weight	30 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data source	Lunar Orbital Study Laser Altimeter

2.10.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating thermal and vacuum range capability
   a. Add an internal heater with thermal switch
   b. Add test chambers and test time for qual and acceptance
   c. Respecify and replace 10 parts for vacuum only
2. Provide interface connector for testing unit to replaceable assembly
   a. Add a 25-pin external interface connector
   b. Add a 15-wire test harness
   c. Add a hard-mounted test signal isolation PCB (6 discretes)
3. Seal the following connectors/wire junctions against moisture
   a. One external interface connector (shell type)
   b. One terminal strip (15 terms)
4. Replace PVC as follows (delta over SEEIR mods)
   a. 25 wire harnesses to 3 assemblies and terms strip and connector
   b. 15 loose wires

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. Model 948 ASSEMBLY NAME CO_2 LASER - SYLVANIA NEXT ASSY NO. ______ DATE 5 / 20/74

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	EXPD.	COST $ MAT'L	LABOR	TOTAL
		Fab Aperture Cover	1	2 50	50	20				5 50		
		Fab Lexan Meter Face & Lens (2)		3 25	1 00	20				3 00		
		Fab Head Plate 18x42		3 00		30				15 00		
		Fab Cage & Install Tube		8 00	2 50	50				18 50		
		Fab Protection Rails	2	2 00		20				10 00		
		Fab Mounting Ears	2	1 00	50	10				6 50		
		Paint Exterior	2			1 00				42 50		
		Replace Tubing	5'		2 50	30				+100 00	20' Min.	
		Rewire W/TFE Est 100			10 00	2 80		5 00		12 50		
		Conformal Coat Trans	3		3 75	60				12 00		
		Conformal Coat PCB	2		2 50	40				6 00		
		Replace Control Knob	1		25					4 50		
		Replace Duodial	1		30					14 50		
		Fab Vespel PB's	2	2 00	30	20				50 00		
		Fab Warning	2	50	30	10				25 00		
		Install Cable Clamps	5	25	25	10				2 50		
		Fab & Install Hose Clamps	5	60	25	10				4 50		
		Replace All Fasteners	150		25 00	16 00	45 00	45 00		37 50		
		Replace Water Tube Clamps	10		60	10				7 50		
		Fab Box & Assembly	AR	1 50	1 00	25	8 00			25 00		
		Other Support & Test				12 00	18 00	8 00	8 00	--		
		150 Hour Bake						16 00		500 00		
		Shock Mounts	AR	4 00	2 00	50		4 00		30 00		
		TOTAL HOURS		28 60	53 50	35 95	71 00	78 00	8 00	932 50		

LOT SIZE FROM	TO	RATE / O.H.	MAT'L	LABOR	TOTAL
		RATE			
		O.H.			
		TOTAL	932 50	8868 86	9801 36
		TOTAL			
		TOTAL			

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5. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

6. Human factors mods as follows

   a. Add silk-screened operating instructions/cautions near controls (2 controls)

2.10.8 Delta Modification Costs

Fabrication	$ 258
Engineering	10,469
Test	4,637
Documentation	2,562
Program Management	896

Total delta modification cost $ 18,822

2.10.9 Data Sources

1. Visual examination

2. Operating instructions - Model 948 CO_2 Laser - Sylvania Corp.

2.11 MICROSCOPE

Manufacturer: American Optical

Model No: H20

Cost: $1576

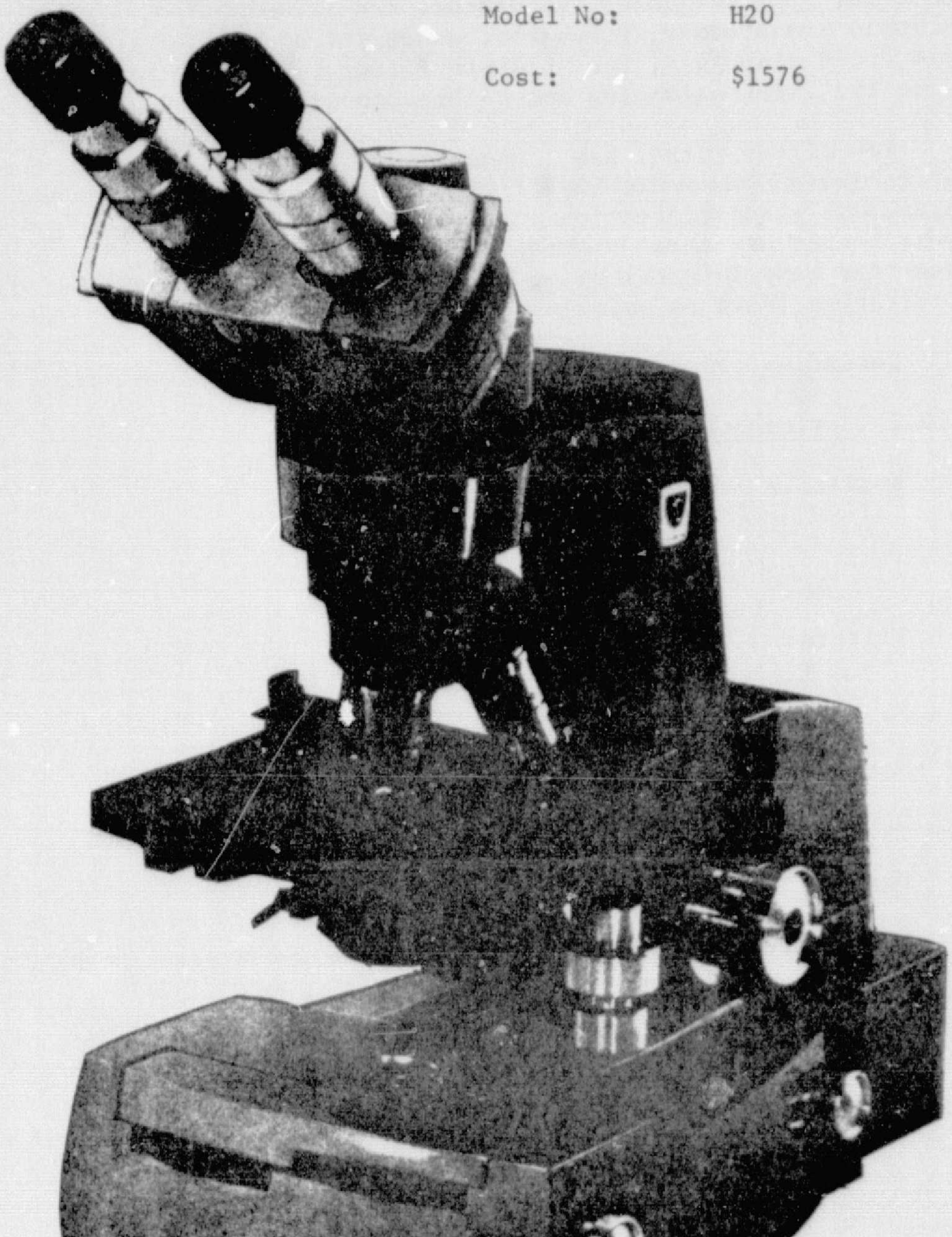

Figure 2.11-1. American Optical Microscope

2.11.1 Description

Models H20 are equipped with high light intensity 12V 100W tungsten halogen lamp, for constant color temperature and illumination, 120V 60 Hz three-step variable transformer, focusable, condenser system, heat absorbing glass, centerable field diaphragm, two built-in filter turrets permitting combinations of selective light balancing and color compensating filters.

Top filter turret has 1 clear aperture, blue daylight filter, blue filter for Polaroid Polacolor Land Film, blue compensated filter for color transparencies, green filter for black & white photomicrography and phase contrast. Lower turret has three neutral density filters and didymium filter. Hinged cover for easy interchange of filters in turrets; additional filters and accessories (such as polarizer) may also be placed within light well.

Satisfies all requirements for Koehler type illumination.

2.11.2 Performance Characteristics

Available lenses:	4 x objective 10 x objective 45 x objective 100 x objective
Filters:	Neutral density 5%, 25%, 50% transmission Didymium color balancing filter Blue daylight Heavy blue polacolor Green

2.11.3 Physical Characteristics

Weight: 20 lb (9 kg)

Dimensions: 16" high 8" wide 10" deep (40 x 20 x 25 cm)

2.11.4 Suitability Analysis

CONSTRUCTION. The microscope is a metal casting with machined parts and glass lenses. Unit can be either bench mounted or stored in a cabinet during boost and moved to a bench while is use. Light supplied by 100 watt bulb.

MATERIALS

- Aluminum
- Glass lamp, filters and lenses
- Plastic heat shield
- Rubber
- Immersion oil

	Disposition		
	Accept	Verify	Unaccept
SHOCK, VIBRATION, ACCELERATION AND ACOUSTIC ENVIRONMENT			
Filters require storage during boost. Held down during operation.			X
Specimen glass, lenses, eyepieces, camera accessories must be stored.			X
Filter lid not positively latched			X
Optical assembly removed by loosening single set screw (Figure 2.11-2)			X

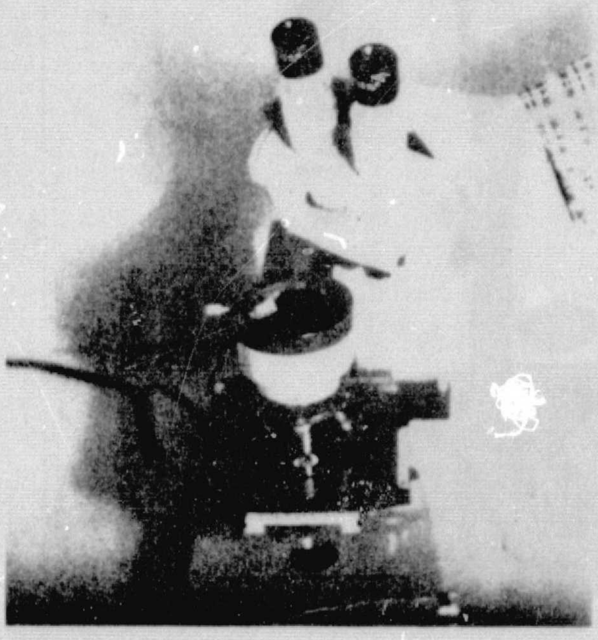

Figure 2.11-2. Removal of Optical Assembly

	Accept	Verify	Unaccept
ELECTRICAL POWER			
110 volts, 60 Hz, 100 watts			
EMI SUSCEPTIBILITY AND RADIATION			
Power supply input requires shield for 10 amp low voltage ac			X
FLAMMABILITY			
Plastic heat shield (see Figure 2.11-3)		X	
Rubber feet		X	

(Disposition: Accept / Verify / Unaccept)

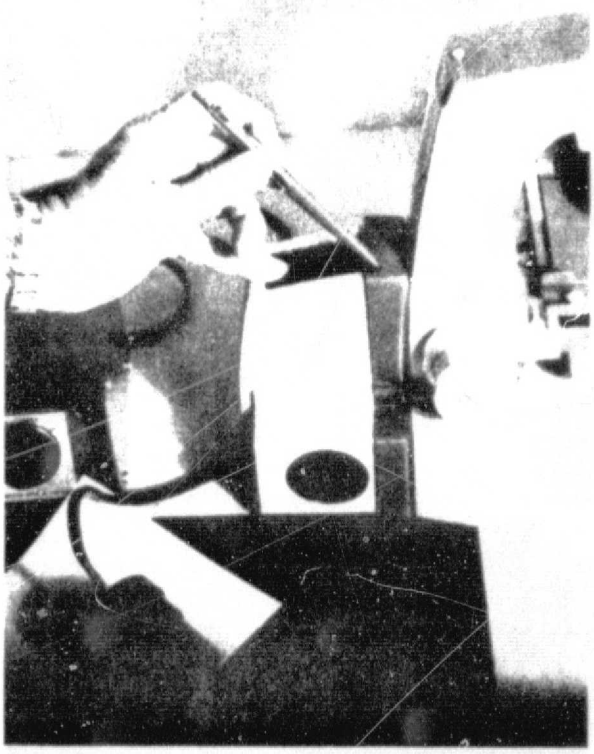

Figure 2.11-3. Plastic Heat Shield

	Disposition		
	Accept	Verify	Unaccept
TOXICITY			
Iodine in lamp (avoid mercury types)	X		
CONTAMINATION GENERATION			
Function of the instrument prevents protection from glass lens shattering. Operational precaution required		X	
Immersion oil			X
ATMOSPHERE			
Compatible with Spacelab atmosphere	X		
AMBIENT TEMERATURES			
Compatible with Spacelab temperatures	X		
EQUIPMENT COOLING			
100 watt light source needs cooling. Lower power source could reduce heat load			X
ZERO-G EFFECTS			
Eyepieces and filters are held in place by gravity (see Figures 2.11-4 and 2.11-5)			X

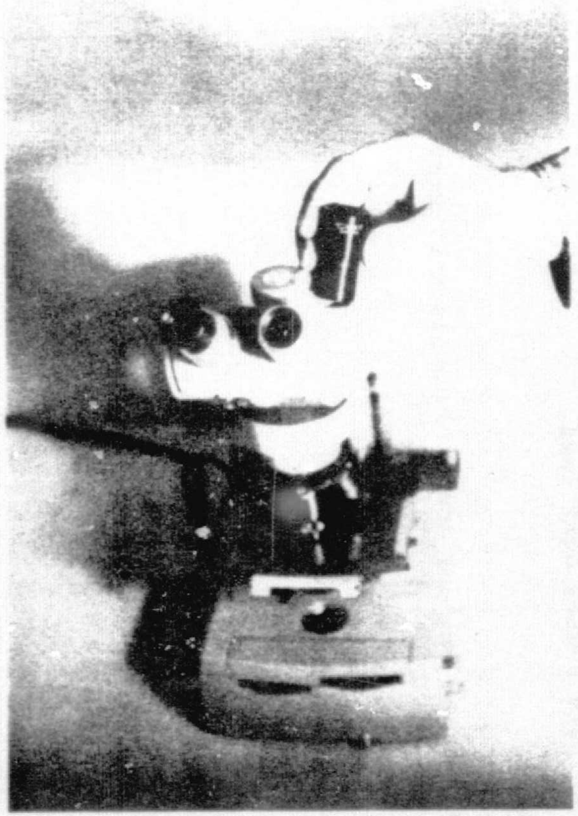

Figure 2.11-4. Eypepiece Held In By Gravity

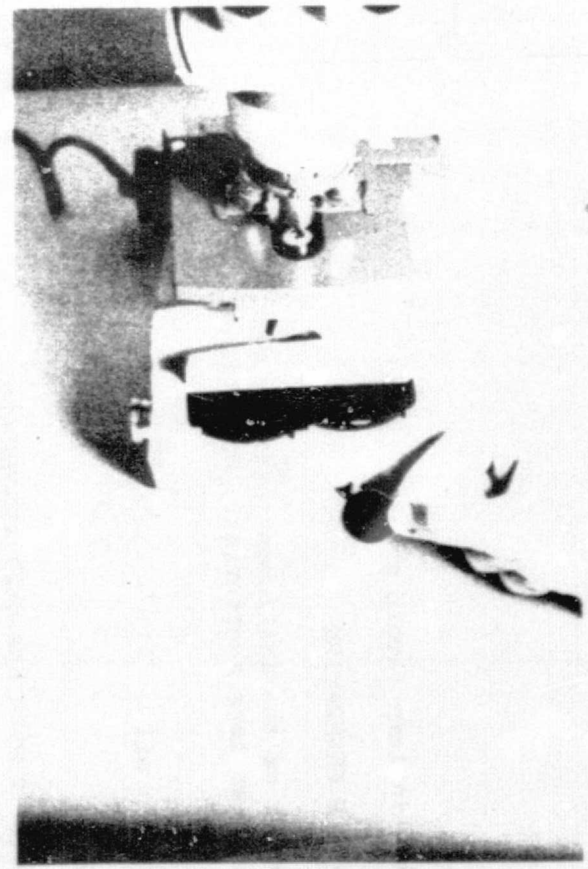

Figure 2.11-5. Filter Held In By Gravity

2.11.5 Modifications

Construction

Shatterables. Removable metal ocular covers required for lens protection when scope is not in use.

9-g Mounting. Adapter plate required for mounting. Suitable hold-downs for slide tray and objective lenses during transport (see Figures 2.11-6 and 2.11-7).

Mounting. 19-inch rack mount not applicable. The microscope will have to be modified by the removal of the four rubber feet exposing existing holes. These holes to be drilled and tapped to accept an NAS 1394C-3 insert or equivalent. This will facilitate the mounting of the adapter plate (see Figure 2.11-6).

Shock-Vibration-Acoustics. It will be necessary to transport this instrument, semi-disassembled, in a suitable metal case (see Figure 2.11-7)

EMI. Shield power supply with metallic enclosure.

Materials

Replace plastic lamp housing with polymide

Thermal

Lamp will need air convection for cooling.

Zero-G Operation

Human Factors and Functional Operation. With instrument bolted to work surface and spring (defined by Figures 2.11-8 and 2.11-9) in place, no operational impairment is foreseen.

Loose Parts/Restraints.

1. Eyepieces require set screw or other restraint system to keep them from drifting away in zero g.
2. Filter assembly needs filter keepers to prevent floating around inside filter compartment (clips allow more filters to be used than one wheel will hold) (5).
3. Pre-load nose piece (holding turrent) to compensate for gravity loss.
4. Filter door latch for zero g.

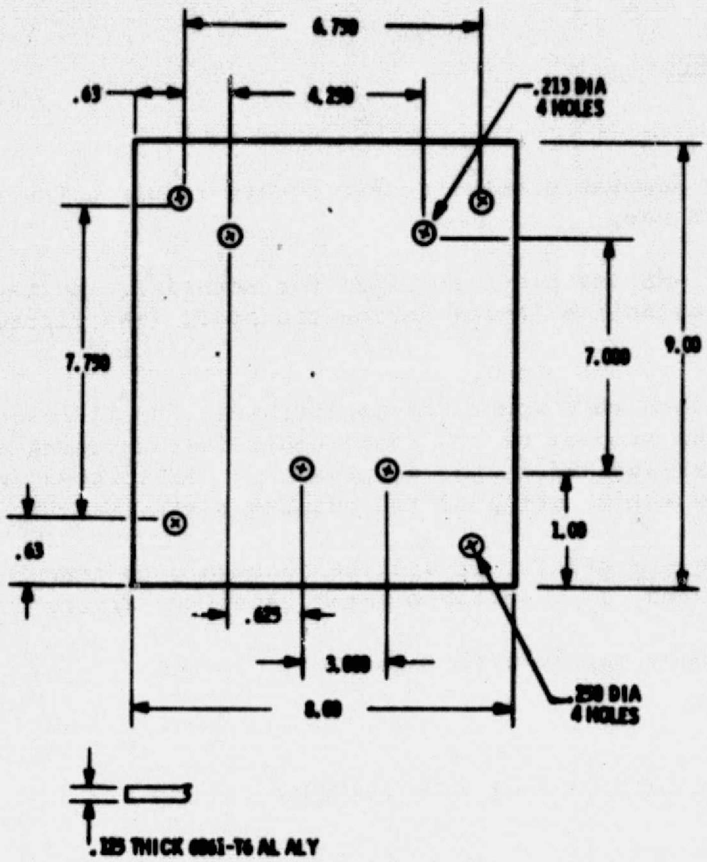

Figure 2.11-6. Microscope Base

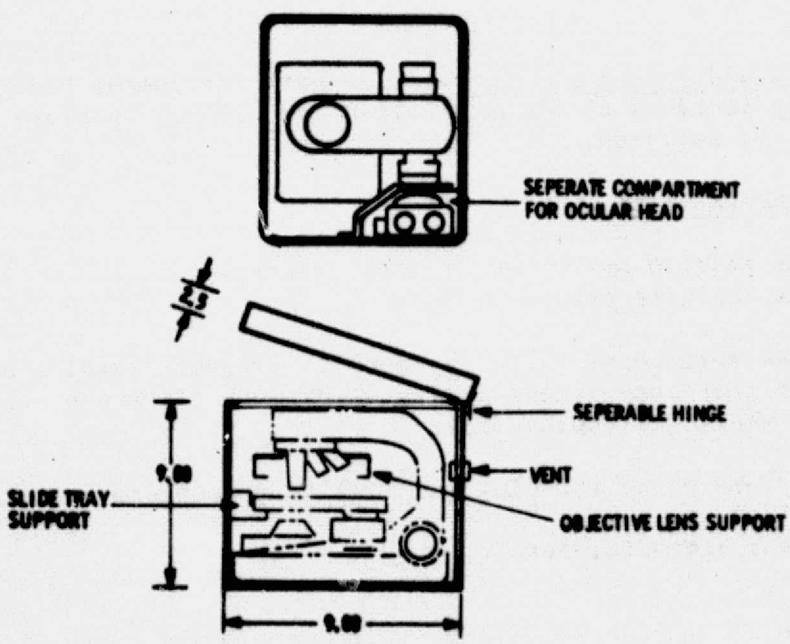

Figure 2.11-7. Microscope Container

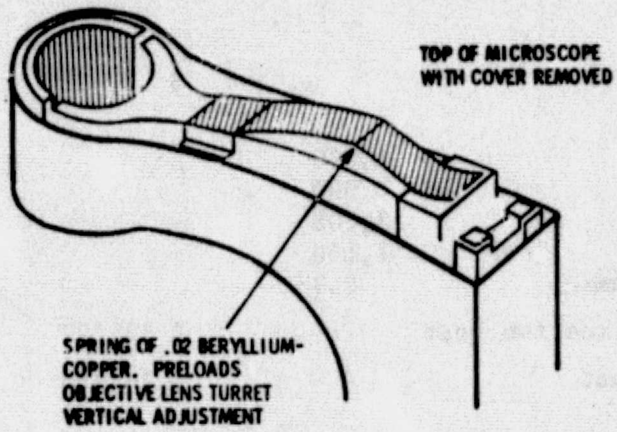

Figure 2.11-8. Microscope Spring Clip Installation

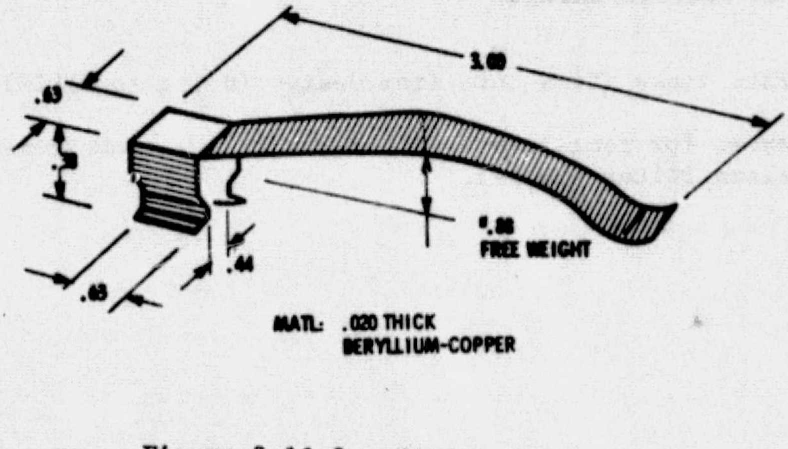

Figure 2.11-9. Spring Clip

2.11.6 Cost Analysis

Modification

Basic Cost		$ 1,809
Modification Cost		
Fabrication	$ 1,330	
Engineering	6.090	
Test	2,208	
Documentation	2,160	
Program Management	589	
Total Modification Cost		$ 12,377
Total Cost		$ 14,186

New Development

Cost	$ 36,000
Weight	20 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Space Station Exp 5.13 Support Equipment

2.11.7 EC006M Delta Modification Requirements Summary

1. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

2. Incorporate loose items into item design (delta to SEEIR)

   a. Redesign for replaceable filter wheels that have cemented in-place filter glasses.

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME Microscope AO #M10TU-FW NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD			COST $: MAT'L	LABOR	TOTAL
		Fab Ocular Covers	2	2.00		.20							5.00		
		Fab. Adapter Plates & Metal Case (Zero Case)		10.00		.20			1.00				20.00		
		Fab. Lamp Housing		8.00		.20			1.00				10.00		
		150 Hour Bake Out					10.00	10.00					350.00		
		Fab. Berllium Copper Spring		1.00		.10			.50				3.00		
		Fab. Ocular Retainer	2	1.00		.10			.25				5.00		
		System Support & Expedite						2.00		1.00					
		Coolant Req. Fan & Housing			8.00								100.00		
		TOTAL HOURS		22.50	8.00		70.00	12.00	2.75	1.00			529.00		
LOT SIZE FROM	TO	RATE													
		O.H.													
		TOTAL											529.00	801.00	1330.00
		TOTAL													
		TOTAL													

Beckman INSTRUMENTS, INC.

SHEET 1 OF 1 BY STATA

Space Division
Rockwell International

2.12 MICROTOME

Manufacturer: American Optical Corp.

Model No.: 820

Cost: $ 1254

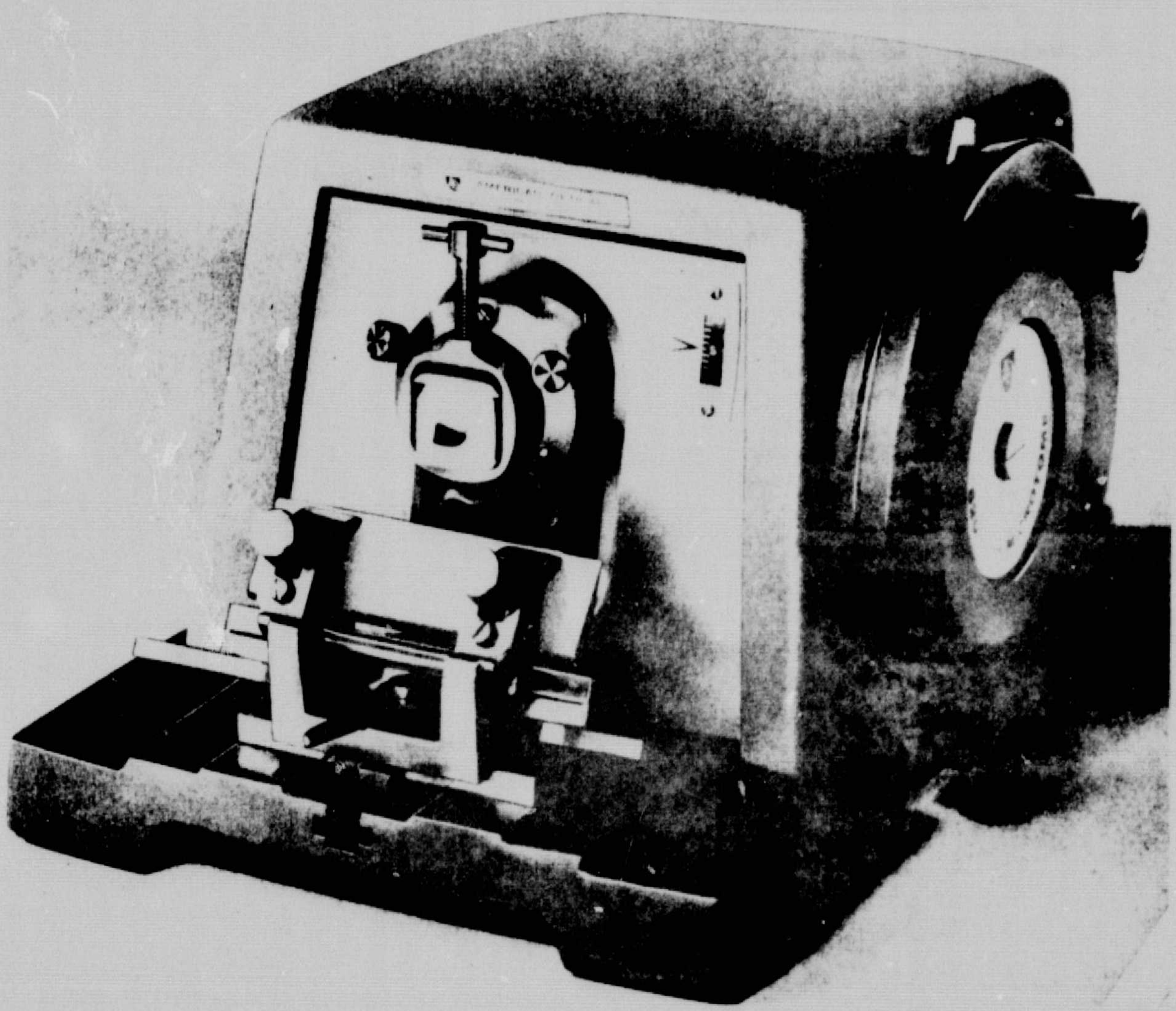

Figure 2.12-1. American Optical Microtome - Model 820

2.12.1 Description

This unit slices very thin sections of specimens for microscopic examination. The unit is hand operated. A crank is turned passing the surface of the specimen across the rigidly-held knife edge.

2.12.2 Performance Characteristics

Section thickness range	1 to 50 microns
Increment	1 micron

2.12.3 Physical Characteristics

Weight: 85 pounds (38.6 kg)

Dimensions: 18" x 14" x 12" (46 x 35.5 x 38 cm)

2.12.4 Suitability Analysis

	Accept	Verify	Unaccept
CONSTRUCTION. The microtome is a large, all metal device with a razor sharp knife edge rigidly attached to the base of the unit. Unit is bench mounted. Blade and carriage is adjustable with thumbscrew tighteners.			
MATERIALS			
Metal Bakelite handles Rubber feet Lubricants			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Carrier is held in place by gravity			X
Crank assembly is not retained			X
Shock absorber required between horizontal slide assembly and advance mechanism			X
Positive handle locks required to keep arms on shaft			X
Store or positively retain knife assembly			
Lock screws/bolts			X
CONTAMINATION GENERATION			
Has exposed lubricants		X	
ATMOSPHERE			
Compatible with Spacelab	X		
AMBIENT TEMPERATURES			
Compatible with Spacelab	X		
EQUIPMENT COOLING			
Not Required			
ZERO-G EFFECTS			
No gravity dependent functions (slice-to-slice repeatability appears independent of gravity)	X		

OPERABILITY	Accept	Verify	Unaccept
Knife requires guard			X
Blade easily removed by loosening knurled knobs. (see Figure 2.12-2). More positive retention required.			

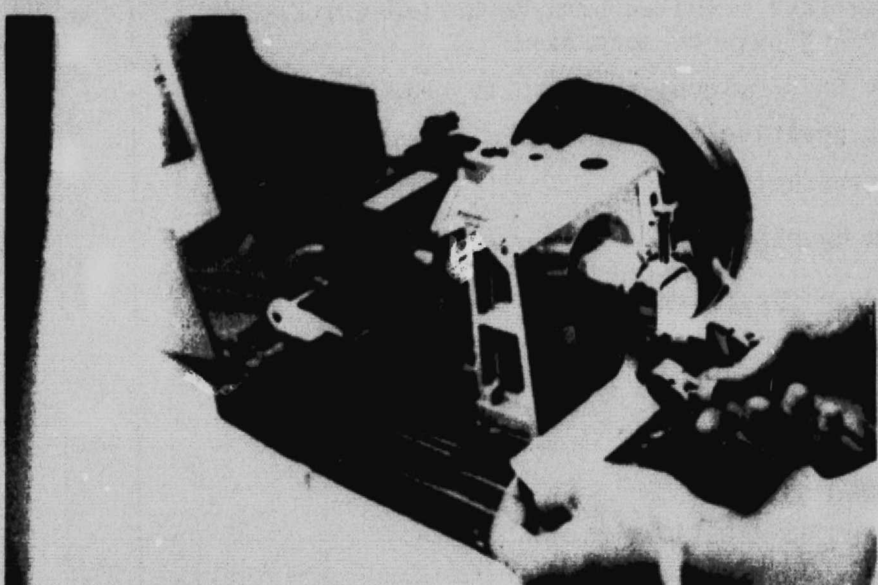

Figure 2.12-2. Microtome Knife Blade

2.12.5 Modifications

Construction

9-g Mounting/Integrity. With all adjustments tight and handwheel locking lever in locked position, Microtome will be rigid enough for this requirement. Base shall be reworked per Figure 2.12-3.

Protrusions and Edges Safety. Required frame as shown in Figure 2.12-4. Fab from aluminum alloy tubing; 1 in. o.d. x 0.031 wall--anodize. Fabricate removable knife guard from 0.031 thick aluminum alloy per Figure 2.12-4--anodize.

Shock-Vibration-Acceleration-Acoustics Resistance. Requires readjustment or correct use after subjected to this category. Fabricate positive safety attachment and fit to crank-locking lever--drill hole in body of instrument to accommodate. Replace all fasteners (estimated quantity, 100) with Nylock. Sheet metal knife guard will retain knife assembly. (Figure 2.12-5)

Materials Usage

Non-Prevelant Commercial Materials (or Warnings on Handling/Usage of Item). All cadmium-plated parts will be stripped and nickel plated--est. 6 small brackets. All fasteners will be changed to CRES. Plastic knobs and handles will be replaced with metal.

2.12.6 Cost Analysis

Modification

Basic Cost		$ 1,440
Modification Cost		
Fabrication	$ 1,751	
Engineering	3,662	
Test	2,208	
Documentation	2,160	
Program Management	476	
Total Modification Cost		$ 10,257
Total Cost		$ 11,697

New Development

Cost	$ 31,000
Weight	50 pounds
Complexity	0.20
State-of-the-Art Factor	2
Data Source	Space Station Exp 5.13

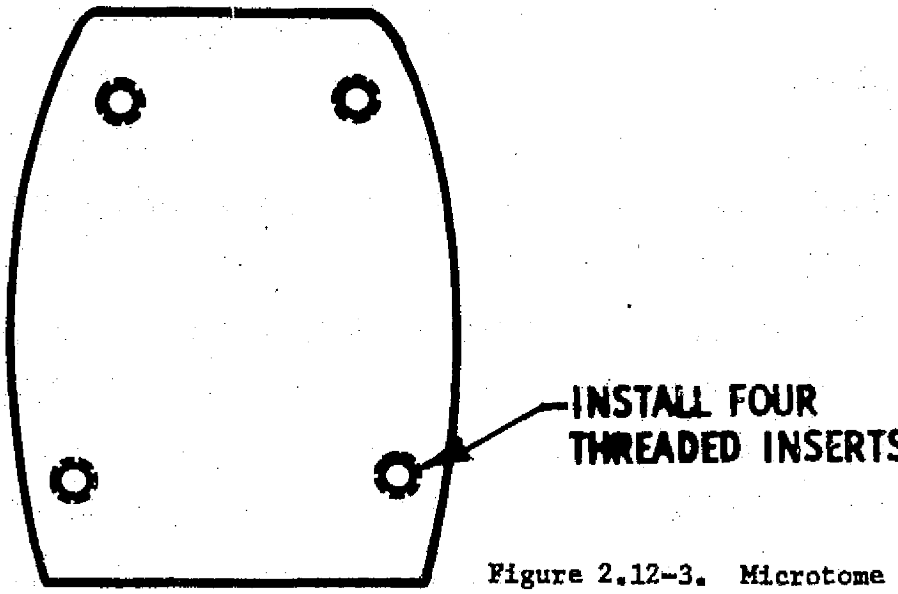

Figure 2.12-3. Microtome Base

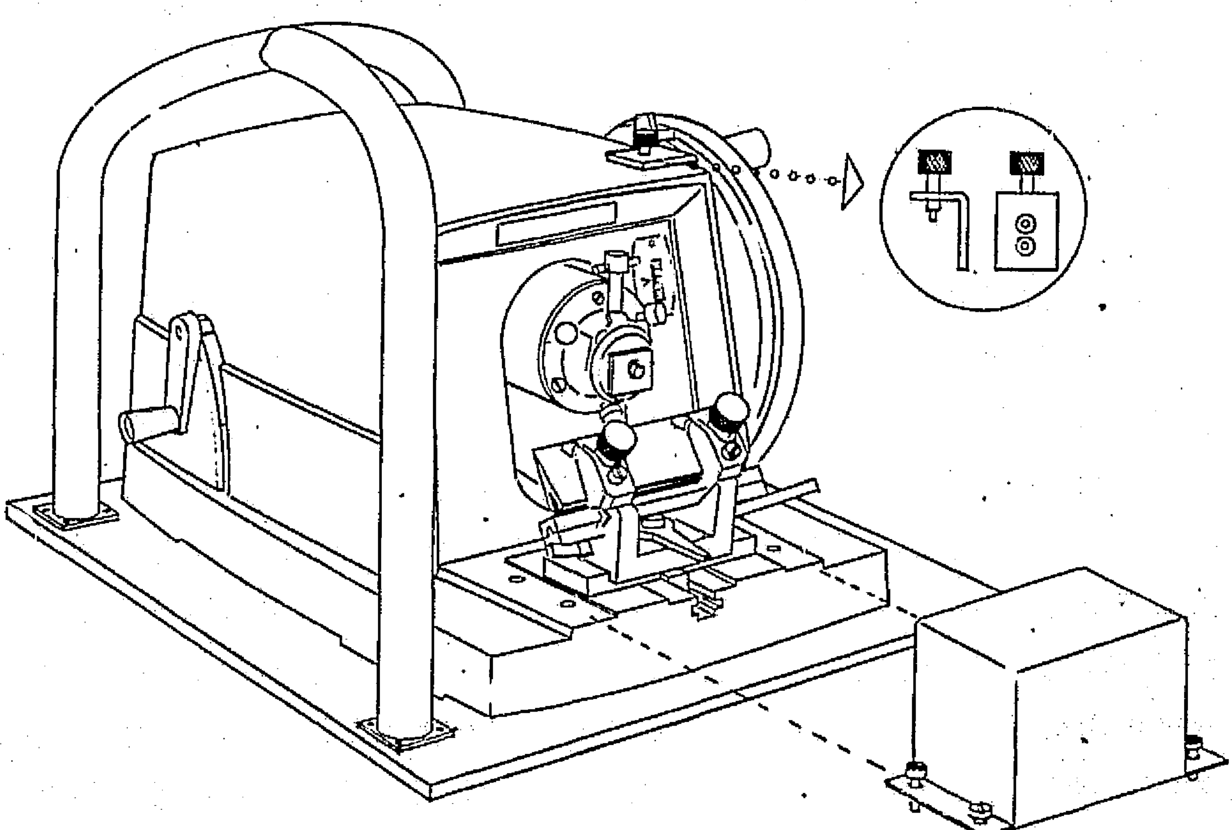

Figure 2.12-4. Protrusion and Edge Protection

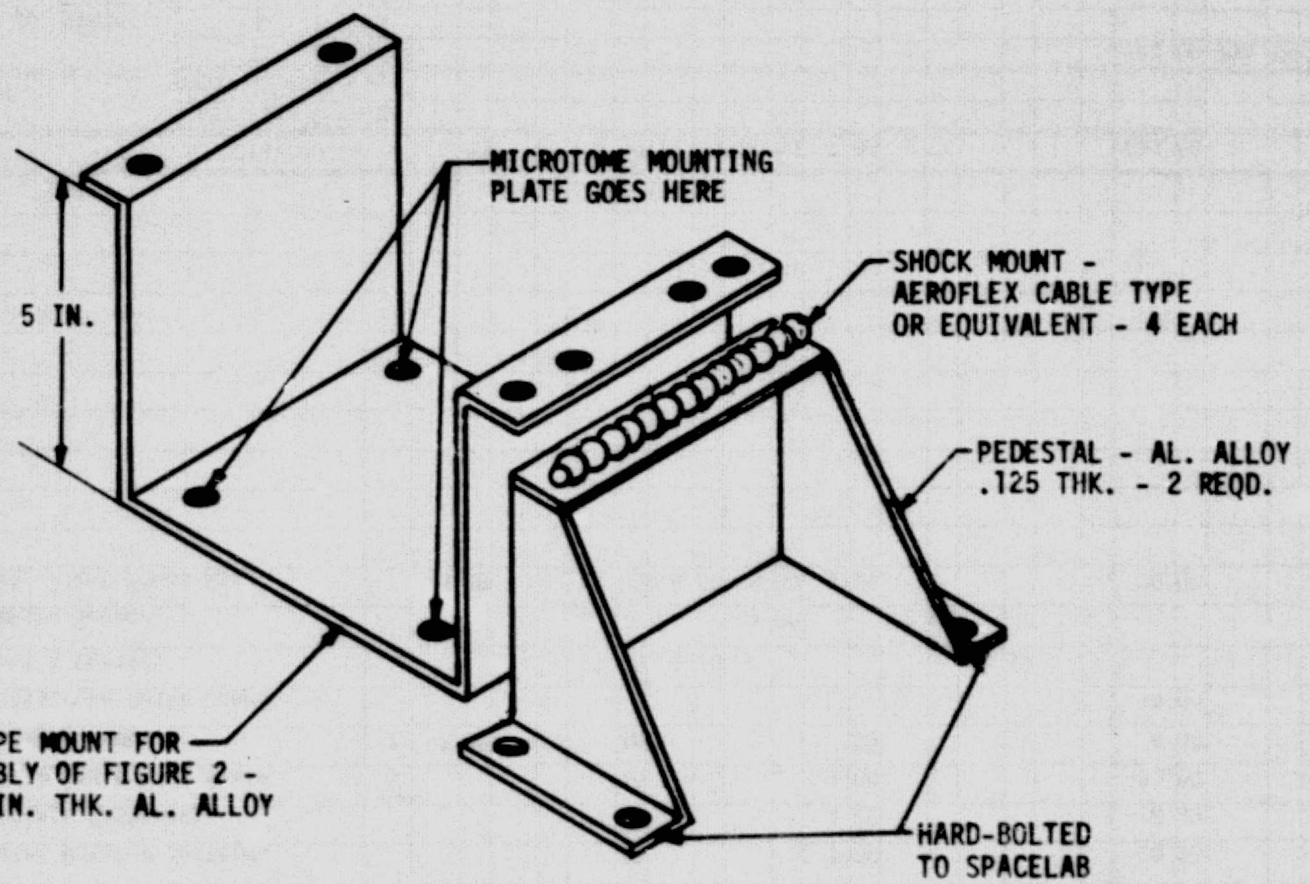

Figure 2.12-5. Microtome Mounting Installation

MANUFACTURING :OST ESTIMATE

ASSEMBLY NO. ________ ASSEMBLY NAME AO Rotary Micortome MD 820 NEXT ASSY NO. ________ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD			COST $ MAT'L	LABOR	TOTAL
		Coolant Req.				10			50				3 50		
		Bakeout						16 00					500 00		
		Fab. Frame		2 00		20			50				10 00		
		Fab. Knife Guard		1 00		10							3 00		
		Fab. & Install Safety Attch.		1 00		10			50				4 00		
		Paint Outside Surfaces				10			1 00				20 00		
		Replace Fasteners				10			1 00				8 50		
		Strip Cad & Nic. Plate	6			10			1 00				60 00		
		Replace Knobs	2	2 00		10			50				4 00		
		Silkscreen Knife Guard											10 00		
		Test & Certify				1 00	4 00								
		System Support						4 00		2 00					
		Fab. Shock Mount Assy		10 00		1 00	8 00	8 00	2 00				20 00		
		TOTAL HOURS		16 00		2 90	12 00	28 00	7 00	2 00			643 00		
LOT SIZE FROM	TO	RATE O.H.													
		TOTAL											643 00	908 02	1751 02
		TOTAL													
		TOTAL													

Beckman INSTRUMENTS, INC.

SHEET 1 OF 1 BY STATA

Space Division
Rockwell International

2.12.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal range capability

   a. Replace lubricants on gear trains, linkages, etc. (no disassembly required)

2. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

3. Human factors modes as follows

   a. Add legends and directional arrows for 2 hand wheels and 2 mechanism lock levers.

   b. Add silk screen operating instructions as unit (8 controls)

   c. Replace cover lid hinge with friction type

2.12.8 Delta Modification Costs

Fabrication		
Engineering	$ 6,311	
Test	4,420	
Documentation	2,562	
Program Management	719	
Total delta modification cost		$ 14,012

2.12.9 Data Sources

1. Visual examination

2. SB820. Model 820 Rotary Microtome, American Optical Corporation, 3.71

2.13 COMMERCIAL OSCILLOSCOPE

Manufacturer: Tektronix

Model No.: 485

Cost: $ 4240

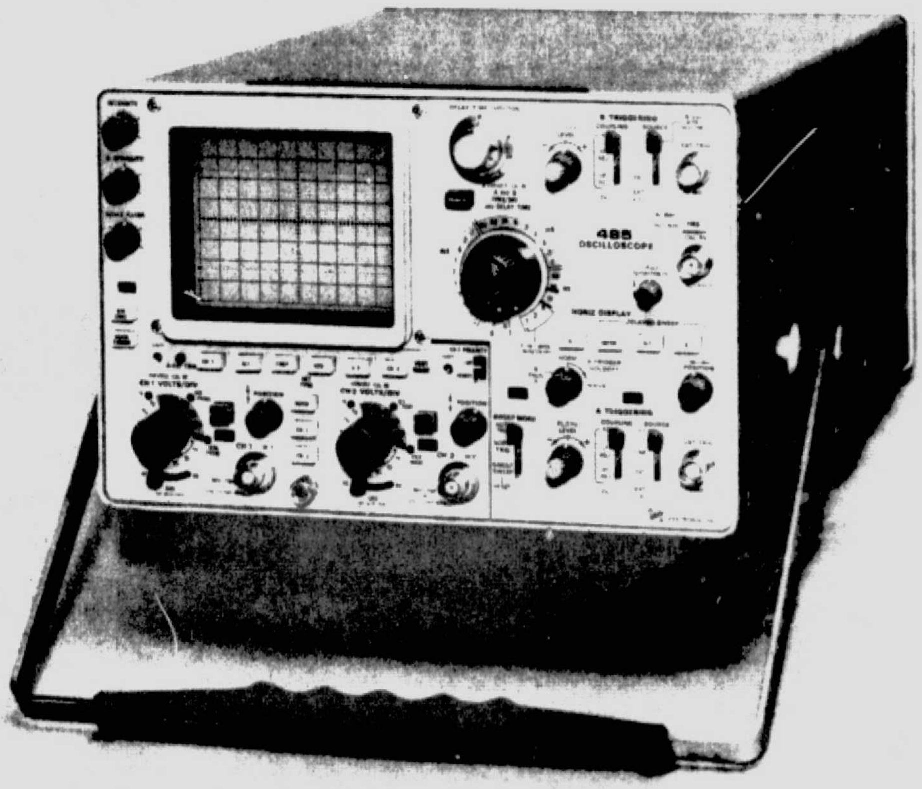

Figure 2.13-1. Tektronix Oscilloscope - Model 485

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2.13.1 Description

The 485 is a 350 MHz, 1 ns/div portable dual-trace oscilloscope. Features include selectable input impedance, adjustable trigger holdoff, EXT TRIG display, alternate delayed sweep, with trace separation control, vertical scale-factor indication, auto-focus, and B sweep intensity control.

The 485 vertical system provides wide bandwidth at full sensitivity with selectable input impedances (350 MHz at 50Ω and 250 MHz at 1 MΩ). Sensitivity is 5 mV/div. Selectable input impedance provides the capability to measure low and high impedance points with the same scope and without active probes. Internal detection circuitry protects the 50-Ω input by automatically disconnecting when the signal exceeds 5 V rms.

Automatic vertical scale-factor readout is provided by three light-emitting diodes located around the edge of each input attenuator knob. A quick glance at the readout tells the operator the correct on-screen volts/div even when the recommended 10X or 100X probes are used.

To complement the higher bandwidth, the 485 has a 1 ns/div sweep. A new alternate sweep mode expands the delayed sweep concept in portables. This feature allows the delayed sweep to appear alternately with the intensified main sweep. In this mode, the operator sees the intensified zone and delayed display at the same time.

The external trigger signal may be viewed on the 485 without disconnecting leads and resetting controls. A front panel push button automatically routes the external signal used to trigger Time Base A to the vertical deflection amplifier. This feature can also be used to quickly make time comparisons between the signal of interest and the external trigger signal.

Full bandwidth triggering and "variable Trigger Holdoff" provide stable presentation of repetitive complex waveforms.

2.13.2 Performance Characteristics

Vertical Deflection (2 Identical Channels)

Selectable Input Impedance. 50-Ω and 1-MΩ impedance are available at a single BNC connector by push button selection.

50Ω within 0.5%; VSWR 1.25:1 or less at 5 mV/div and 10 mV/div, 1.15:1 or less from 20 mV/div to 5 V/div to 350 MHz.

Bandwidth and Risetime at all Deflection Factors from 50-Ω Terminated Source.

	-15 C to + 35 C	+35 C to +55 C
50Ω	DC to 350 MHz, 1 ns	DC to 300 MHz, 1.2 ns
1 MΩ	DC to 250 MHz, 1.4 ns	DC to 200 MHz, 1.8 ns

Deflection Factor. 5 mV/div to 5 V/div in 10 calibrated steps (1-2-5 sequence), accurate within 2%. Uncalibrated, continuously variable between steps and to at least 12.5 V/div. Gain can be recalibrated at the front panel.

Display Modes. Channel 1; Channel 2 (normal and inverted); Alternate; Chopped (approximately 1-MHz rate); Added; X-Y (channel 1-Y and channel 2-X).

Automatic Scale Factor. Probe tip deflection factors for 10X and 100X coded probes are automatically indicated by three readout lights at the edge of the knob skirts. All lights are off when the channel is not selected for display or when the trace identification control on the probe is depressed.

Horizontal Deflection

Time Base A and B. Calibrated sweep range; 1 ns/div to 0.5 s/div in 27 calibrated steps (1-2-5 sequence). Uncalibrated A is continuously variable between steps and to at least 1.25 s/div.

Time Base A and B Sweep Accuracy.

Sweep Rate	+15 C to +35 C	-15 C to +55 C
1 ns/div to 20 ns/div	±3%	±5%
50 ns/div to 0.1 s/div	±2%	±4%
0.2 s/div and 0.5 s/div	±3%	±5%

Calibrated Sweep Delay

Delay Time Range. 0 to 10 times Delay Time/Div setting of 10 ns/div to 0.5 s/div.

Differential Delay Time Measurement Accuracy.

Delay Time Setting	+15 C to +35 C
10 ns/div and 20 ns/div	±(1% of measurement + 0.2% of full scale)
50 ns/div to 1 ms/div	±(0.5% of measurement +0.1% of full scale)
2 ms/div to 0.5 s/div	±(1% of measurement +0.1% of full scale)

Full Scale is 10 times the Delay Time/Div setting

Jitter. 1 part or less in 20,000 of 10X the Time/Div setting.

Triggering A and B

A Trigger Modes. Normal, sweep runs when triggered. Automatic, sweep free-runs in the absence of a triggering signal and for signals below 20 Hz. Signle Sweep, sweep runs one time on the first triggering event after the reset selector is pressed.

B Trigger Modes. B Runs After Delay Time, starts automatically at the end of the delay time. B Triggerable After Delay Time, runs when triggered. The B (delayed) sweep runs once, in each of these modes, following the A sweep delay time.

Time Base A and B Trigger Sensitivity.

Trigger Mode		To 50 MHz	To 350 MHz
DC	Internal	0.3 div deflection	1.5 div deflection
	External	20 mV	100 mV
AC		Signals below 16 Hz are attenuated	
AC LF Reject		Signals below 16 kHz are attenuated	
AC HF Reject		Signals below 16 Hz and above 50 kHz are atteunated	

Jitter. 0.1 ns or less at 350 MHz and 1 ns/div.

CRT

Tektronix CRT. Four-inch rectangular tube; 8 x 10-div display area, each div is 0.8 cm. Horizontal and vertical centerlines further marked in 0.2-div increments. P31 phosphor normally supplied; P11 optional without extra charge; 21-kV accelerating potential.

Other Characteristics

Two-Frequency, Fast Rise Calibrator. Output resistance is 450Ω with a risetime (positive slope) into 50Ω or 1 ns or less. 1-kHz, duty cycle 49.8% to 50.2%. Amplitude is 5 V within 0.5% into 1 MΩ and 0.5 V within 1% into 50Ω (±0.5%). Optional BNC accessory current loop provides 50 mA within 1%. Selectable repetition rates are 1 kHz and 1 MHz within 0.25%. Specifications apply over +15 C to +35 C range.

A Sweep Output. Open circuit, approximately 10V positive-going sawtooth; into 50Ω, approximately 0.5 V.

A and B Gate Outputs. Open circuit, approximately 4 V positive-going rectangular pulse; into 50Ω, approximately 0.5 V.

2.13.3 Physical Characteristics

	Cabinet		Rackmount	
Dimensions	in.	cm	in.	cm
Height	6.6	16.8	7.0	17.7
Width	12.0	30.5	19.0	48.3
Depth			18.0	45.7
handle extended	20.6	52.3		
handle not extended	18.5	47.0		
Weights (approx.)	lb	kg	lb	kg
with accessories	24	10.9		
without accessories	21	9.5	26.2	11.9

Included Accessories. 50-Ω 18-inch BNC cable (012-0076-00); two BNC jack posts (012-0092-00); 50-Ω termination (011-0049-01); accessory pouch (016-0535-00). Rack models also include mounting hardware and slide out assembly (351-0101-00).

2.13.4 Suitability Analysis

	Disposition: Accept	Verify	Unaccept
CONSTRUCTION. This portable oscilloscope consists of densely packaged electronic components installed on an aluminum frame (see Figure 2.13-2). The exterior surface is sheet aluminum. The unit can be obtained in a rack-mounted configuration.			
MATERIALS			
Acrylonitrile Butadrene-styrene (ABS) Acetal resin Aluminum Epoxy Glass Polyethylene Polyamides (nylon) Polyvinylchlorides Polyvinyl acetate (cabinet paint) Polyurethane (foam fan filter) Phenolic			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
<u>Shock</u>. Operating and nonoperating: 30 g's, 1/2 sine, 11-ms duration, 2 shocks per axis in each direction for a total of 12 shocks.	X		
<u>Vibration</u>. Operating: 15 minutes along each of the three axes, 0.025 inch peak-to-peak displacement (4 g's at 55 Hz) 10 to 55 to 10 Hz in 1-minute cycles.		X	
Toroidal inductors are held by leads only (Figure 2.13-3)			X
Plug-in IC's and transistors are not positively retained			
Transistor heat radiators not positively retained			X
Screws and knobs not staked			X
ELECTRICAL POWER			
Recessed slide switch selects nominal operating line range. Line voltage range is 90 V to 136 V and 180 V to 272 V. 60 watts maximum power consumption at 115 V. Line frequency 48 to 440 Hz.	X		

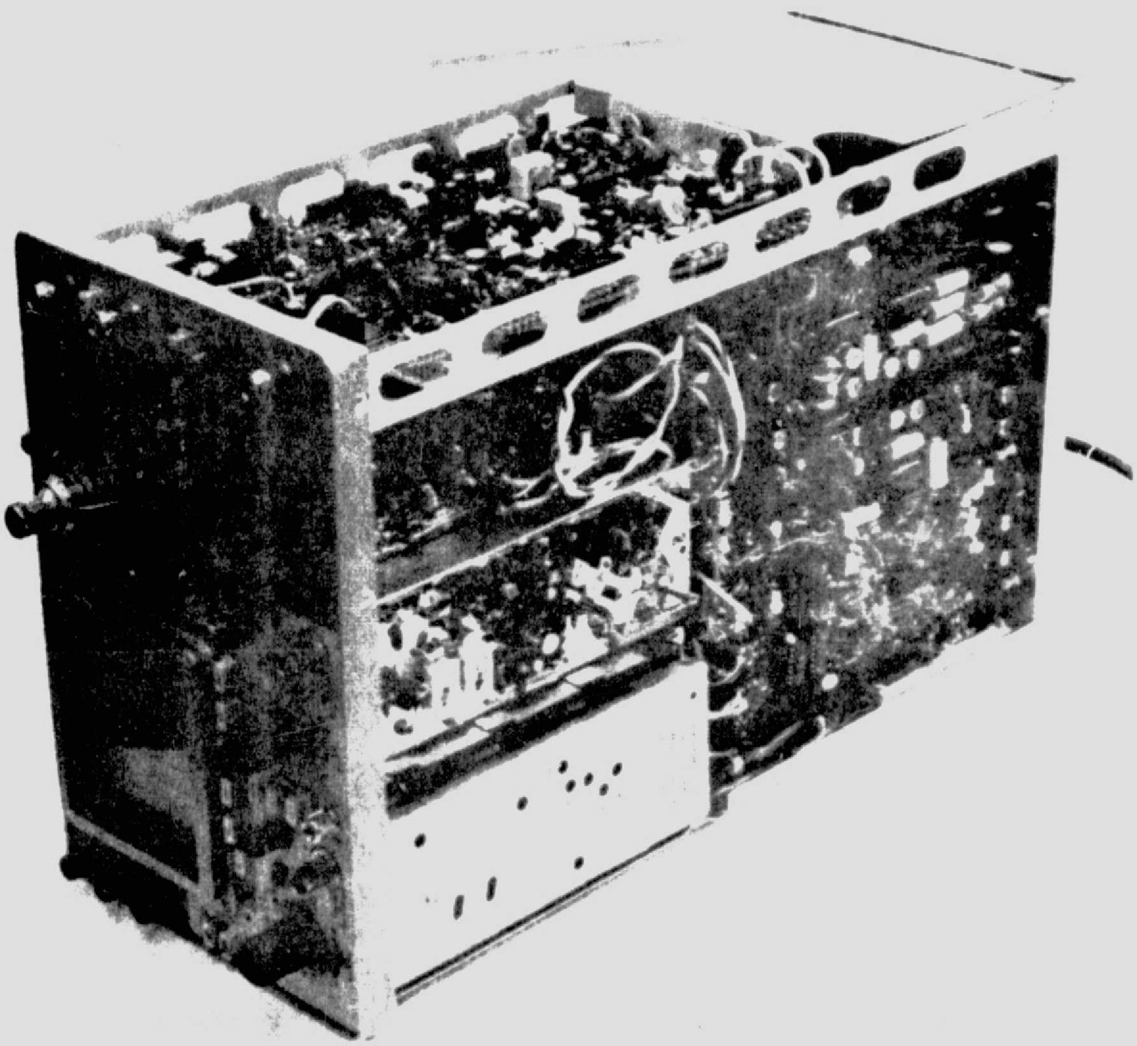

Figure 2.13-2. Oscilloscope Internal Arrangement

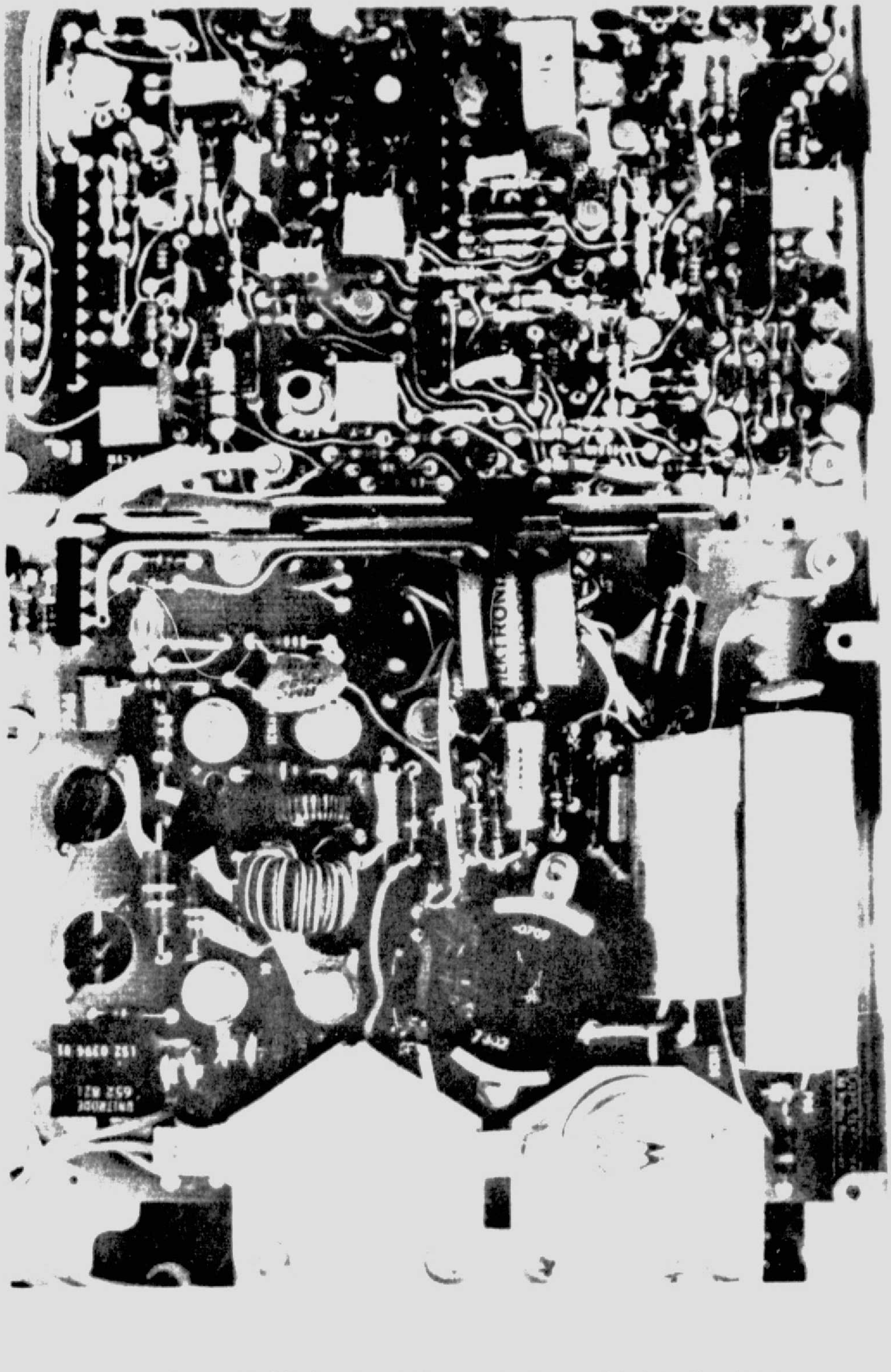

Figure 2.13-3. Lead Supported Toroidal Inductors

	Disposition		
	Accept	Verify	Unaccept
EMI SUSCEPTIBILITY AND RADIATION			
Kit available to make it consistent with MIL-1-1681D.	X		
RF shielding practices for covers, etc.	X		
Signals returned to chassis.			X
NOISE GENERATION			
Fan noise <40 db	X		
FLAMMABILITY			
Circuit boards		X	
ABS plastic knobs		X	
PVC insulation		X	
TOXICITY			
Polyurethane foam fan filter			X
CONTAMINATION GENERATION			
Glass CRT could shatter and particles escape unit (Figure 2.13-4)			X
ATMOSPHERE			
Humidity. Operating and storage: 5 cycles (120 hours) to 95 percent relative humidity referenced to MIL-E-16400F (para. 4.5.9 through 4.5.9.5.1, class 4).	X		
AMBIENT TEMPERATURES			
Altitude. Operating: to 15,000 feet; maximum allowable ambient temperature decreased by 1°C/1000 feet from 5,000 to 15,000 feet. Nonoperating to 50,000 feet.	X		

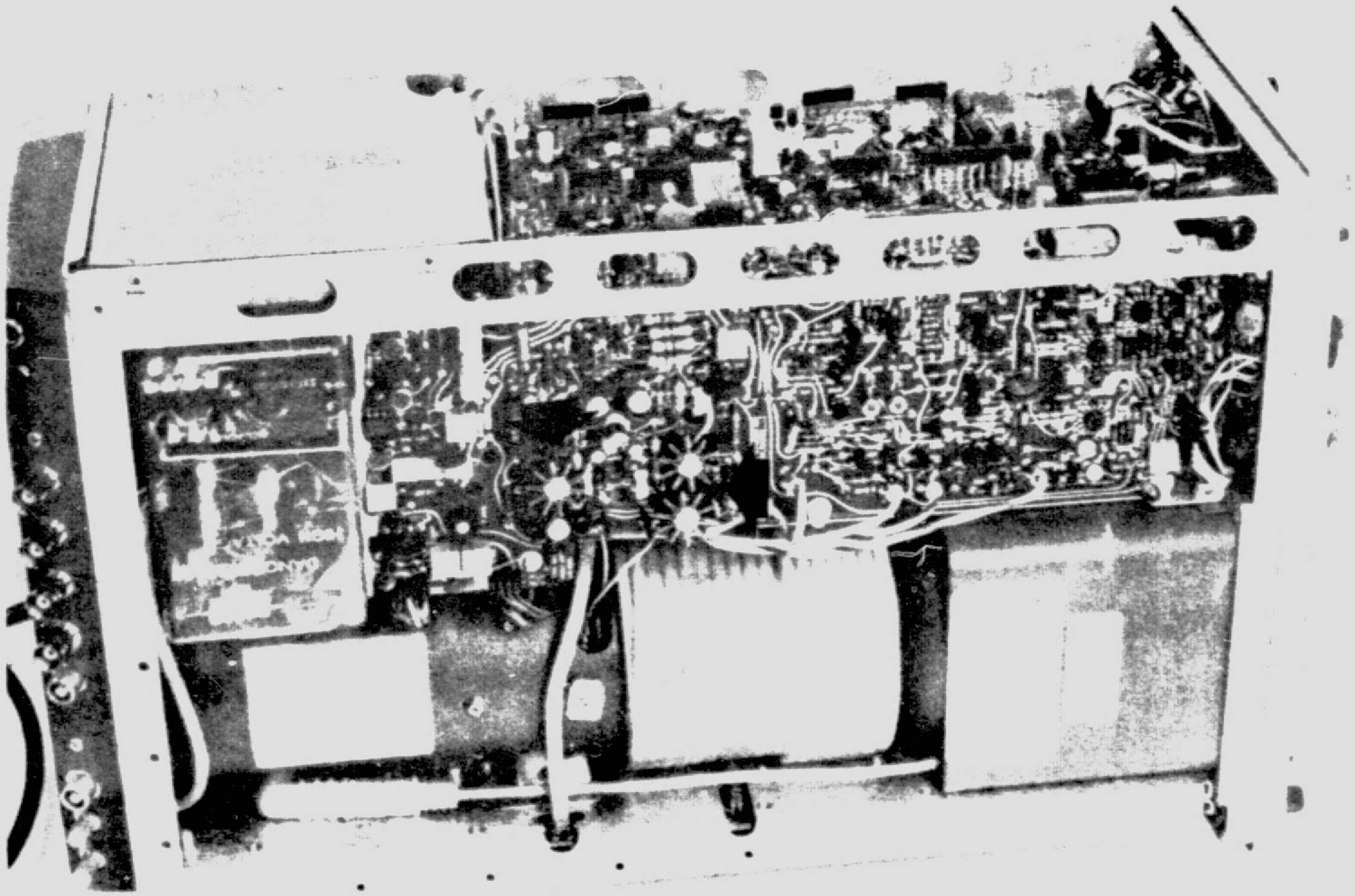

Figure 2.13-4. CRT Containment and Transistor Heat Dissipators

	Disposition		
	Accept	Verify	Unaccept
EQUIPMENT COOLING			
<u>Ambient Temperature</u>. Operating: -15 C to + 55 C. Filtered forced air ventilation is provided. Storage: -35 C to + 75 C.	X		
Has internal fan (Figure 2.13-5) Finned dissipator on transistors (Figure 2.13-4)	X		
ZERO-G EFFECTS			
No gravity dependent functions	X		
OPERABILITY			
Requires protrusion protection			X

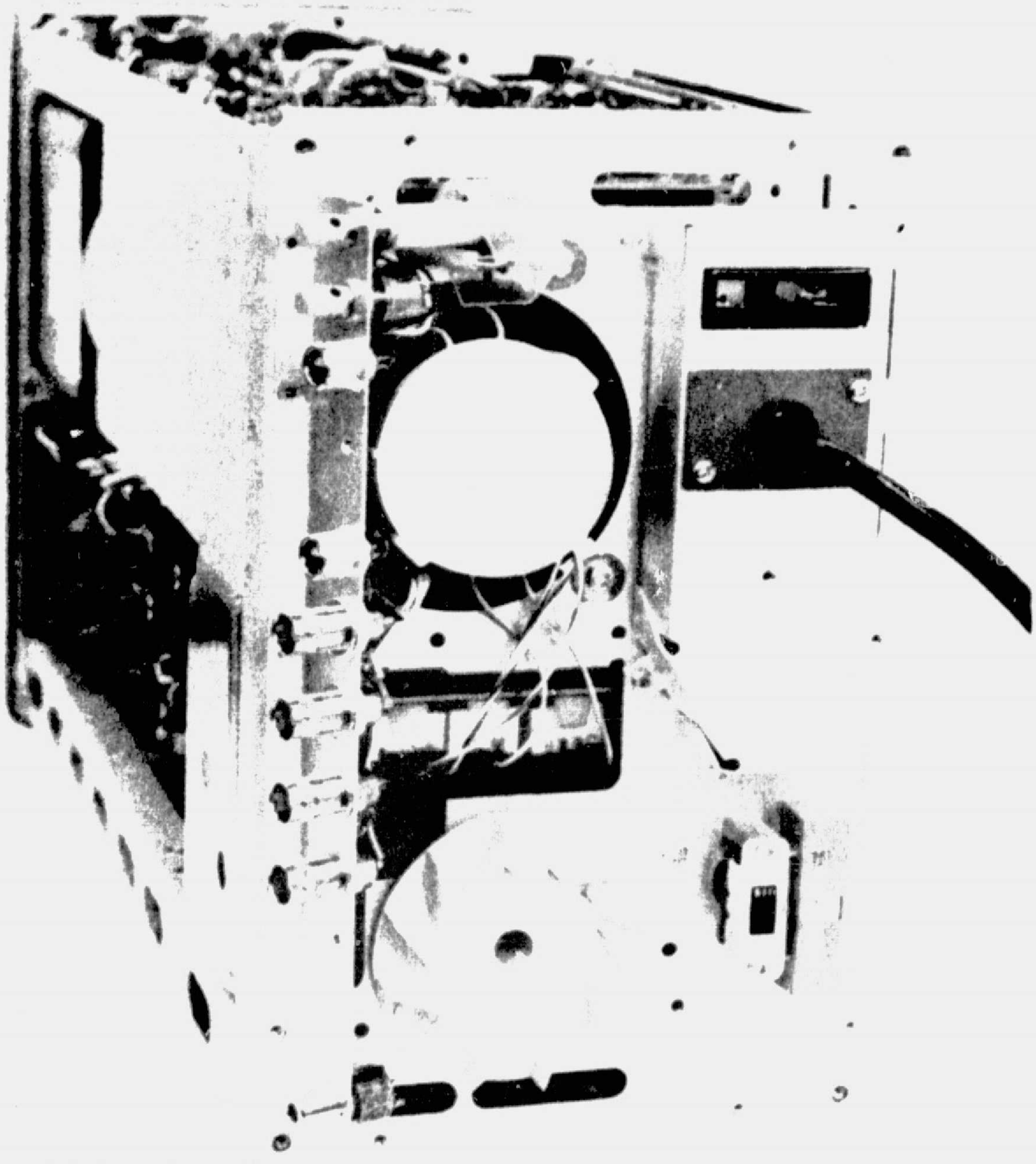

Figure 2.13-5. BNC Connectors and Fan Installation - Rear of Unit

2.13.5 Modifications (see Figure 2.13-6)

Construction

Shatterables.

1. Lexan cover for face of CRT. An insert 3" x 3-1/2" will slip right in.

2. CRT is adequately covered on rear; so containment of fragments not a problem, except one grommet needed around HV lead. Air outlets need fine screens.

3. Seal switch on front panel.

Protrusion and Edges. Many protrusions (knobs) on front--obviously unavoidable. Fab radiused bezel to go around face of instrument.

Shock-Vibration-Acceleration-Acoustic.

1. Circuit boards although large, are well supported. CRT is adequately supported.

2. Components in general: conformal coat all boards, masking connectors and pots.

3. Toroid inductors in P/S section: Some extra support, such as tying with lacing cord, is needed in addition to support from conformal coat.

4. Pin connectors: These need to be secured against backing out. Some metal plates with stiff foam blocks properly placed will give them adequate support. Need two such plates; one for RH side and one for bottom.

5. TO5 transistor heat sinks: secure to transistor bodies with Glyptal.

6. Large capacitors in P/S section: tie down with lacing cord.

7. Replace fuse holder.

8. Pin all knobs to shafts or levers.

9. Replace all fasteners with CRES Nylok type.

Material

1. Has Hg elapsed time indicator - change to a safer type.

2. Replace all plastic knobs with metal.

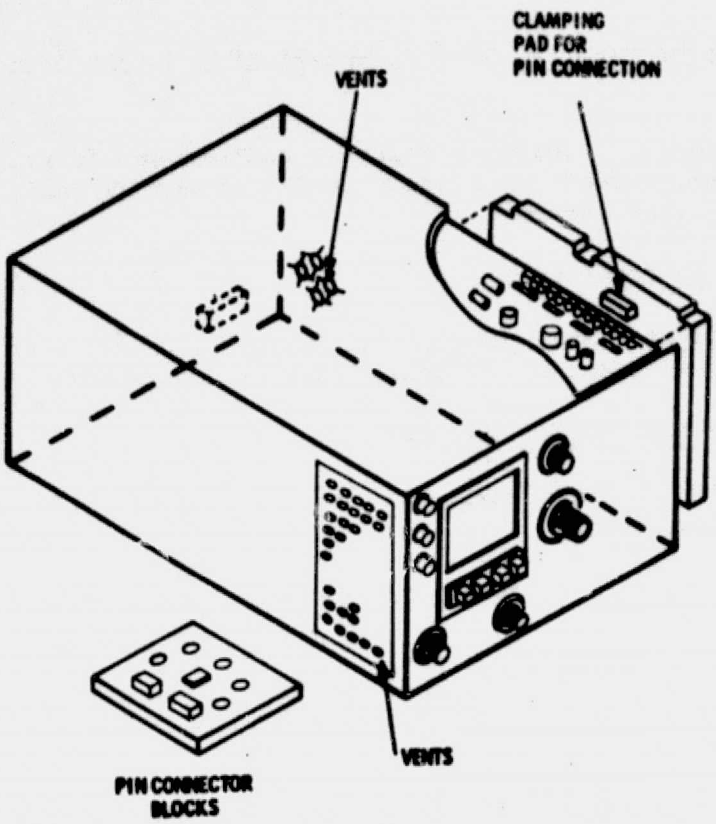

Figure 2.13-6. Oscilloscope Modifications

3. Bake out for 150 hours to expel volatiles.

4. Upgrade wire harnesses to A/B rating.

2.13.6 Cost Analysis

Modification

Basic Cost		$ 4,868
Modification Cost		
Fabrication	$ 9,352	
Engineering	13,119	
Test	4,416	
Documentation	2,160	
Program Management	1,328	
Total Modification Cost		$ 30,375
Total Cost		$ 35,243

New Development

Cost	$ 326,000
Weight	20 pounds
Complexity	2.00
State-of-the-art Factor	2
Data Source	Shuttle Orbiter Communications

2.13.7 EC006M Delta Modification Requirements Summary

1. Provide delta non-operating vacuum and thermal range capability (1.6 psia and -31 F baseline)

   a. Respecify and replace 100 electronics parts (primarily for vacuum)

   b. Provide delta vacuum chamber and test time (only) for qual and acceptance testing

   c. Replace fan motor lubricants

2. Provide connector interface for testing item to removable assembly level

   a. Add two 50-pin external interface test connectors

   b. Add a 100-wire test harness to 15 replaceable assemblies

   c. Add a hardmounted test signal isolation circuit board (40 discretes)

   d. Note: no PCB patch wiring--direct wire harness to signal takeoffs.

52-23-07.1

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME Scope - Tektronix Model 485 NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	COST $: MAT'L	LABOR	TOTAL
		Lexan Cover for CRT Face		1 00		10				5 00		
		Grommet for HV Lead			10					50		
		Fine Screens for air ports		2 50	1 00	25				5 00		
		Fab. Radius Bezel to Protect Front Face		8 00		25				20 00		
		Conformal Coat all PCB's				4 00			48 00	28 00		
		Mask Conn. & Pots										
		Note: Requires Hand Solder all Plug in Components							10 00			
		Tie Down Inductors							50			
		Pin Conn. Securing Plates	2	16 00						10 00		
		Glyptal Head Sinks to TO-5 Cans										
		Note: Use Thermal Silver Epoxy			1 00	20				21 00		
		Tie Down Caps	2		25					2 00		
		Replace ET Meter								35 00		
		Fab. Bracket Mfg.		4 00	50	20				10 00		
		Replace All Plastic Knobs w/Metal-Assume 50% Commercial								400 00		
		Knobs Available-Fab. 50%		10 00		1 00				15 00		
		Replace Fuse Holder		1 00		10			50	2 00		
		Seal or Boot Switch Slots		6 00		50		8 00	8 00	50 00		
		TOTAL HOURS										

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			O.H.
			TOTAL
SHEET 1 OF 2 BY STATA			TOTAL
			TOTAL

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52-23-07.1

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME Scope - Tektronix Model 485 NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD	Instru. Library		COST $: MAT'L	LABOR	TOTAL
		Seal Front End Circuitry	2	20 00		1 00		5 00	8 00				25 00		
		Operations Required to Perform													
		Part I:													
		Disassemble Instrument and						30 00	30 00						
		Document for Reassembly													
		Outside Processing of Fab.											100 00		
		Parts (Finishes, Etc.)													
		Reassemble Instrument						25 00	36 00				5 00		
		Hard Solder all Wire Conn.			3 00	1 00									
		Test & Realign					80 00								
		Certified Fab. By Instrument									40 00				
		Library													
		System Support & Expedite				20 00		40 00		30 00			100 00		
		150 Hour Bake Out						16 00					500 00		
		Rewire w/TFE	100		10 00	1 00		5 00	5 00				30 00		
		Pin All Knobs & Buttons	40	10 00		5 00							4 00		
		Replace all Hardware	150			4 00			6 00				37 50		
		TOTAL HOURS		78 50	15 85	38 60	80 00	129 00	152 00	30 00	40 00		1037 00		
		LOT SIZE FROM / TO	RATE												
			O.H.												
			TOTAL										1037 00	8314 52	9351 52
			TOTAL												
			TOTAL												

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3. Seal the following connectors/wire functions against moisture

   a. Twenty 3- to 6-pin internal interface connectors (flexible plastic molded) (no PCB printed pins used)

   b. Nine external interface BNC coax connectors

4. Replace PVC as follows (delta to SEEIR mods only)

   a. 50 loose wires

5. Human factors mods

   a. Redesign for plug-in PCB's with designated test points (approximately 10 PCB's and connectors needed) for repackaging of electronics)

6. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

2.13.8 Delta Modification Costs

Fabrication	$ 1,143	
Engineering	29,182	
Test	5,318	
Documentation	2,562	
Program Management	1,910	
Total delta modification cost		$ 40,115

2.13.9 Data Sources

1. Visual examination

2. Model 485 Oscilloscope Maintenance Manual, Tektronix, Inc.

3. Tektronix Products 1974 Catalog

2.14 MILITARY OSCILLOSCOPE

Manufacturer:	Hewlett Packard
Model No.:	AN/USM-281A
Cost:	$ 3100

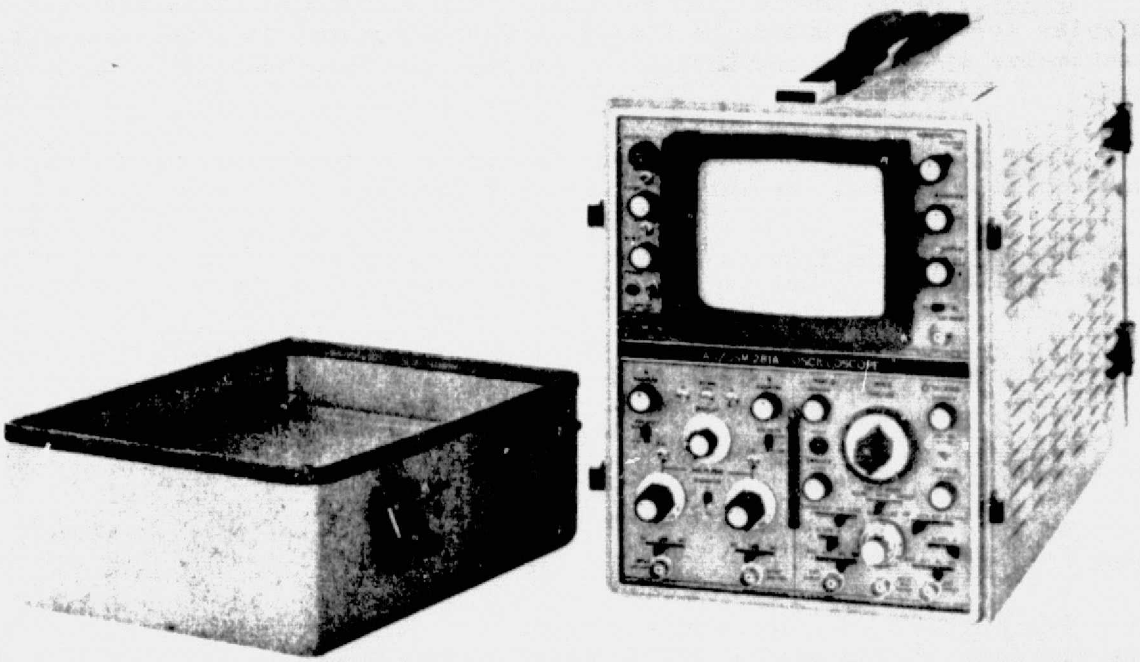

Figure 2.14-1. Hewlett Packard Military Oscilloscope

2.14.1 Description

This unit is a portable oscilloscope that meets military specifications for electrical performance as well as environmental performance. Its bandwidth is from dc to 5 MHz.

2.14.2 Performance Specifications

Cathode-Ray Tube and Controls

Type. Post accelerator, 12 kV accelerating potential; aluminized P31 phosphor (other phosphors available) NESA coated safety glass face plate.

Graticule. 8 x 10 cm parallax-free internal graticule.

Display Area. Meets MIL-O-24311(EC) for 10 cm horizontal and 6 cm vertical display area, ±3 cm about the center horizontal graticule line. The additional centimeter at the top and bottom of the graticule provides additional viewing area.

Beam Finder. FIND BEAM control brings trace to CRT screen regardless of horizontal, vertical, or intensity control settings.

Intensity Modulation. Approximately +2 V, dc to 5 MHz, blanks trace of normal intensity. Input resistance approximately 5100 ohms.

Intensity Control. Adjusts beam intensity from extinguished to a point that overrides the unblanking gate.

Focus Control. Adjusts spot for minimum size within the 6 x 10 cm CRT graticule area.

Astigmatism: A front panel screwdriver control provides circular adjustment of spot.

Trace Align. A front panel screwdriver control to align the trace with the graticule ±2 degrees about the graticule horizontal centerline.

Calibrator. 1 kHz square wave, <3μs risetime, 10 V and 250 mV amplitude, ±2%.

Horizontal Amplifier

Bandwidth. dc to 5 MHz dc-coupled; 5 Hz to 5 MHz ac-coupled.

Risetime. <175 ns with <2% overshoot, ringing, or spurious response.

Sensitivity. Continuously adjustable from 0.1 V/div to 1.0 V/div.

Input Impedance. 1 megohm ±2% shunted by <35 pF.

Positioning Controls. Coarse and fine positioning controls position the start of a trace over any horizontal point on the screen.

Horizontal Magnifier. X1, X5, X10, ±5% (for 3% accuracy time base plug-ins).

2.14.3 Physical Characteristics

Weight: 28 pounds 8 ounces without plug-ins (12.9 kg)

Dimensions: 21-1/4 x 7-7/8 x 12 (53 x 20 x 37 cm)

2.14.4 Suitability Analysis

	Accept	Verify	Unaccept
CONSTRUCTION. Portable, battery operated oscilloscope built for field use by the military. CRT covered with safety glass. Bench top operation.			
MATERIALS			
Glass Aluminum Plastic PVC wire insulation			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Vibration meets MIL-0-24311(1.3 g @ 25 Hz)			X
Shock - MIL-STD-901, grade A, class 1	X		
Visual Exam (assumed)			
Circuit boards require additional support for vibration			X
ELECTRICAL POWER			
115 V or 230 V ±10%, 50 to 400 Hz, 125 watts maximum (with heater energized)	X		
DATA MANAGEMENT COMPATIBILITY			
Visual readout			
Emitter follower outputs for main and delayed gates, main and delayed sweep	X		
EMI SUSCEPTIBILITY AND RADIATION			
Meets MIL-STD-462 for CE01, 03, CS 01, 02, 06, RE01, 02, RS01, 03 test	X		
Class II A - MIL-STD-461	X		
FLAMMABILITY			
PVC wire insulation			X
CONTAMINATION GENERATION			
CRT is not totally enclosed. Possible fragment if CRT shatters.			X

	Disposition: Accept	Verify	Unaccept
CONTAMINATION SUSCEPTIBILITY			
Drip proof: non-operating - per MIL-STD-108	X		
Salt spray: non-operating - per MIL-E-16400	X		
RELIABILITY			
Tested per MIL-0-23411(EC). Eight instruments operated for total of 2630 operating hours at 40 C and vibrated at 25 Hz with an amplitude of 0.020 inch for 10 minutes of each hour of "on" time during each day of the 8-hour manned cycled. The input power was removed for 10 minutes of each 4 hours during the same manned test schedule. Proven MTBF of 600 hours with 99 percent confidence level.	X		
ATMOSPHERE			
Non-operating - 50,000 ft Operating - 25,000 ft	X		
0 - 95% relative humidity	X		
AMBIENT TEMPERATURES			
Non-operating - 62 C to 75 C Operating - 28 C to 65 C	X		
EQUIPMENT COOLING			
Unit cooled by natural convection			X
ZERO-G EFFECTS			
No gravity dependent functions	X		
Accessories need restraint			X
OPERABILITY			
Required protrusion protection while installed in rack			X

2.14.5 Modifications

Construction

Shatterables. CRT - protect by replacing existing glass shield with Lexan shield. Add fine stainless screen to louvered openings to prevent particle egress.

Protrusions and Edges Safety. Recess instrument for protrusion protection (approximately 2.5 inches). (See Figure 2.14-2)

19-Inch Rack Mount Capability. (See Figures 2.14-2 and 2.14-3)

1. Fabricate brackets for panel mount - 0.125 thick aluminum, clear anodized

2. Fabricate rails for chassis support - 0.125 thick aluminum, clear anodized

Shock-Vibration-Acceleration-Acoustics Resistance.

1. Conformal coat circuit boards

2. Restrain circuit boards from oil-canning per design guidelines 1.0

3. Pin 12 knobs to their shafts

4. Add plastic threaded standoff to center of large circuit boards to limit flexing (est. 6 pieces)

Materials Usage

Concentrations of Flammable/Unident. Materials. Replace all knobs with metal. Slide switch buttons to be replaced with polyimide buttons. All wiring to be replaced with TFE insulated wires. Coating on circuit boards to make them A/B flammable.

Non-Prevelant Commercial Materials (or Warnings on Handling/Usage of Item). All internal brackets (est. 12) and chassis (est. 4) that are cadmium plated to be stripped and nickel plated. Replace all fasteners with CRES, Nylok (est. 200 fasteners).

Thermal Compatibility

Provide screened holes top and bottom for additional cooling. Existing design has louvers on both sides (see Figure 2.14-4).

Atmosphere Contamination Compatibility

Oscilloscope to be baked for several hours at an elevated temperature to "bake off" toxic gasses from solvents, epoxies, etc., used during fabrication.

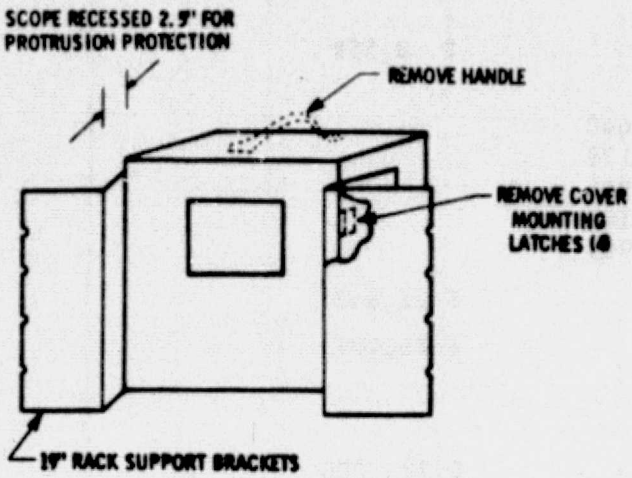

Figure 2.14-2. Oscilloscope Installation

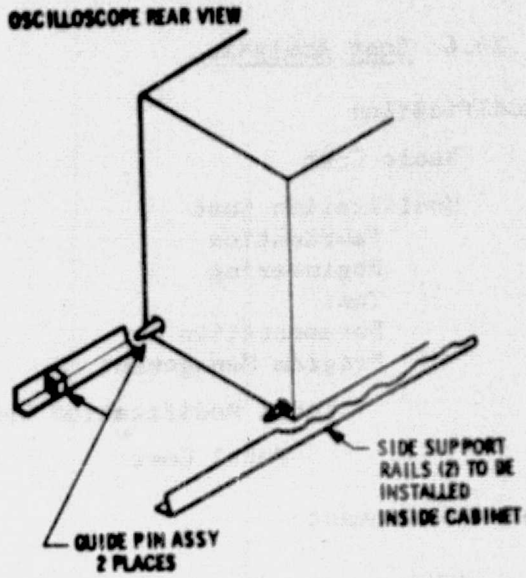

Figure 2.14-3. Oscilloscope Rail Pin/Guide Installation

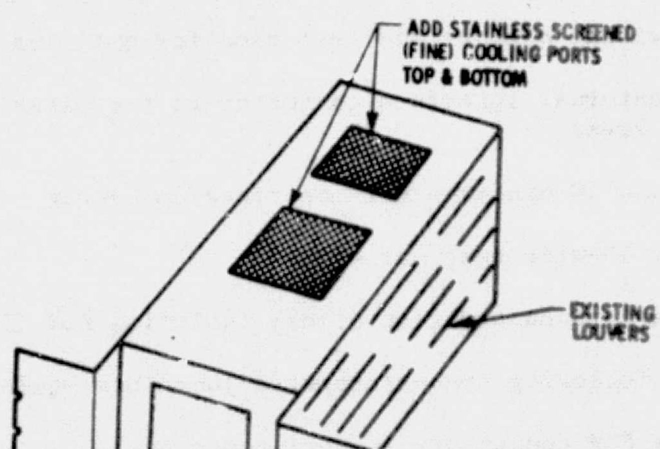

Figure 2.14-4. Oscilloscope Porting

2.14.6 Cost Analysis

Modification

Basic Cost		$ 3,559
Modification Cost		
Fabrication	$ 8,640	
Engineering	7,139	
Test	2,944	
Documentation	2,160	
Program Management	965	
Total Modification Cost		$ 21,848
Total Cost		$ 25,407

New Development

Cost	$ 129,000
Weight	10 pounds
Complexity	1.0
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter Communications

2.14.7 EC006M Delta Modification Requirements Summary

1. Provide nonoperating vacuum (only) capability
   a. Respecify and replace 75 electronic parts for vacuum
   b. Add vacuum chamber and test time for qual and acceptance
2. Provide external interface connector to test item to replaceable assembly level
   a. Add one 50-pin external interface connector
   b. Add a 50-wire test harness
   c. Add a hardmounted test signal isolation PCB (20 discretes)
3. Seal the following connectors/wire junctions against moisture
   a. Three PCB connectors (no printed pins)
   b. Two internal major plug in interface connectors
4. Replace PVC as follows (delta to SEEIR mods)
   a. 100 loose wires

C-3

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. AN/USM-281A ASSEMBLY NAME Oscilloscope - HP NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	FAB	ASS'Y	INSP.	TEST	M.E.	EXPD	INST. LIB.		MFG TECH	MAT'L	LABOR	TOTAL
		Lexan Shield for CRT		1 00		10							5 00		
		Screen Lowered Openings	2	2 50	1 00	25							5 00		
		Fab. Recess Brks.	2	2 00		20							9 00		
		Fab. Rails & Blocks	2	3 50	1 00	20							22 50		
		Overspray Exterior	AR			2 00							75 00		
		Fab. Metal Knobs	13	13 00		1 00							30 00		
		Fab. Slide Switch Buttons	13	13 00		1 00							195 00		
		Rewire w/TFE x	150		15 00	10 00		25 00				25 00	25 00		
		Strip & Replate Brkt. & Chassis	16										160 00		
		Fab. & Screen Holes Top and Bottom	AR	6 00	2 00	60							5 00		
		150 Hour Bake Out	AR					16 00					500 00		
		Support of Above Items				20 00		25 00	30 00						
		Disassemble & Document						30 00				30 00			
		Reassemble Instrument						25 00				36 00			
		Test & Realign					80 00								
		Calibration Certification								40 00					
		Conformal Coat PCB's				4 00						48 00	21 00		
		Pin Knobs to Shafts	12	1 20									3 60		
		Secure PCB's	6	3 00	60	30							2 10		
		TOTAL HOURS		45 20	19 60	39 65	80 00	121 00	30 00	40 00		139 00	1058 20		

LOT SIZE FROM	TO	RATE										MAT'L	LABOR	TOTAL
		O.H.												
		TOTAL										1058 20	7581 70	8639 90
		TOTAL												
		TOTAL												

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5. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

2.14.8 Delta Modification Costs

Fabrication	$ 698	
Engineering	21,712	
Test	5,005	
Documentation	2,562	
Program Managment	1,499	
Total delta modification cost		$ 31,476

2.14.9 Data Sources

1. Technical Brochure, Ruggedized Oscilloscope AN/USM-218A, Hewlett Packard, May 15, 1969

2.15 PARTICLE COUNTER

MANUFACTURER: ORTEC

MODEL NO.: 401A, 109A, 410, 435, 415

COST: $ 3000

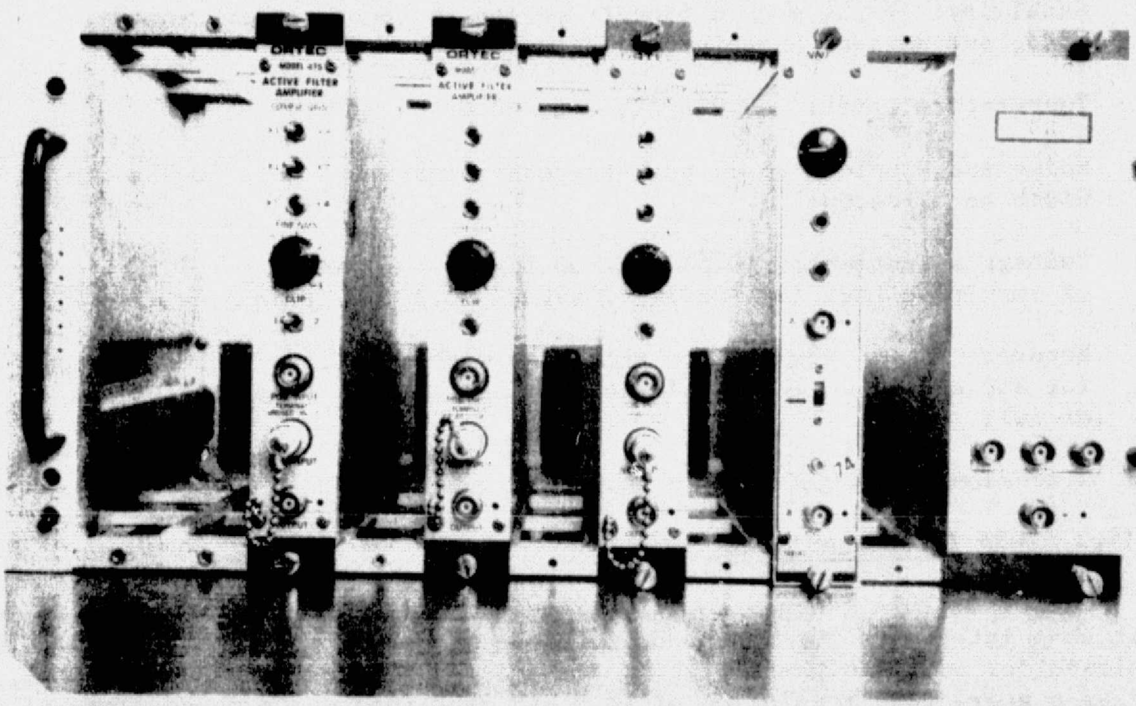


Figure 2.15-1. Partial Assembly of Ortec Particle Counter

The Ortec particle counter is made up of five components. Specifications for four of these units are presented.

2.15.1 401A/402A Modular System Bin and Power Supply

The 401A/402A Modular System Bin and Power Supply provides housing and operating voltages for up to 12 NIM standard modules. The 401A Bin is built for adjustment-free module entrance, with low coefficient of friction and anti-galling action. The rear panel supports 12 connectors and the power supply. Connectors are wired for +24 v, -24 v, +12 v, -12 v, +6 v, -6 v, and 115 v ac. Mechanical construction exceeds TID-20893 (Rev.) type 1, class A requirements.

Specification

Input: 103 to 129 v or 210 to 258 v ac. 50 to 65 Hz. (Input current for 72-w output, 115-v input, is 1.8 A.)

Regulation: ±0.05% over combined range of zero to full load and input voltage of 88% to 110% of rated input over any 24-hr period after 60-minute warmup.

Stability: ±0.3% over a 6-month period at constant line voltage, load, and ambient temperature, after 24-hour warmup.

Temperature Drift: <0.01%/°C, 0 to 60 C

Noise and Ripple: <3 mV peak-to-peak as observed on a 50-MHz bandwidth oscilloscope.

Voltage Adjustment: ±0.5% minimum range; resetability ±0.05% of supply voltage (typically ±1 v); Z_o <0.3Ω any frequency ≤100 kHz.

Recovery Time: <50 μsec to return to within ±0.1% of rated voltage for any change in input voltage and load current from 10% to 100% of full load.

Dimensions: 19.0 x 8.719 x 16.0 in. (48.2 x 22.1 x 40.7 cm)

2.15.2 109A FET Preamplifier

The Ortec 109A charge-sensitive FET-input Preamplifier is an all-silicon unit that integrates the charge output from semiconductor detectors. It is designed for use in high-resolution charged-particle spectroscopy systems. It has a guaranteed resolution of <2.5 keV FWHM (Ge) and a noise slope of ≤25 eV/pF.

Specification

Performance.

Integral Nonlinearity: $\leq 0.1\%$ for 0 to ± 4.7-v output

Charge Sensitivity: 150 mV/MeV referred to silicon; 186 mV/MeV referred to germanium; 540 mV/10^6 electrons; measured using X10 Gain.

Noise: <2.5 keV FWHM (Ge) at 0-pF input capacitance

Slope: ≤ 0.025 keV/pF

Temperature Stability: $\pm 0.01\%/°C$

Maximum Detector Bias: 100 V dc (BNC detector input connector)

Detector Load Resistor: 100 MΩ

Open Loop Gain: 20,000

Control.

Gain: Gain may be changed by a factor of 10 by Gain toggle switch, X1 and X10 positions.

Inputs.

Signal: Accepts positive or negative charge input (normally from a semiconductor detector) from any type of detector; BNC (UG-1094/U) connector.

Bias: Accepts detector bias from bias supply and applies it to detector through the signal connector; maximum ± 1000 V; SHV (AMP-51494-2) connector or Ortec type C-38.

Output.

Pulse Shape: Dependent upon input capacitance; ∿15 nsec rise time (10 to 90%) with 10 pF using X1 Gain; 50-μsec fall time constant. Pole-zero-cancellation circuit incorporated for optimum resolution and overload performance.

Amplitude: 0 to 7 V max dynamic range.

Impedance: 93Ω as shipped, variable from 50 to 150Ω

Weight (Net). 1.12 lb (0.5 kg)

Dimensions. 1.75 x 4 x 6 in. (4.45 x 10.2 x 15.3 cm) plus power cable

2.15.3 410 Linear Amplifier

The Ortec 410 Linear Amplifier provides complete flexibility of pulse shaping methods to optimize either energy or time resolution or to effect a compromise as the experiment dictates. Single or double-delay-line shaping can be selected, or single or double differentiation with time constants from 0.1 to 10 μsec can be used. The very low input noise level is well suited to high-resolution spectroscopy with semiconductor or gaseous detectors, while the overload-handling capability is suited for use with various scintillation detectors.

Simultaneous unipolar (singly differentiated) and bipolar (doubly differentiated) outputs at the two common impedance levels are included. In normal applications the unipolar output signal can be used for optimum energy resolution and the bipolar signal can furnish optimum time resolution. A preamplifier power output connector on the rear panel can furnish operating power to any Ortec transistorized preamplifier.

Specification

Performance.

Amplifier Noise: Equivalent noise at the unipolar output when referred to the input is less than 7 μV rms using maximum gain and RC pulse shaping with 1st Differentiation and Integration both set for 1-μsec pulse shaping.

Overload Performance: Amplifier recovers from a X300 overload to less than 2% of rated output voltage within 4 μsec using maximum gain and the double-delay-line shaping mode. The comparable overload factor using RC pulse shaping is X100.

Count Rate Stability: The shift in gain as a function of counting rate is less than 0.2% for 50,000 counts/sec from a ^{137}Cs source with a 60-keV threshold on the counting.

Amplifier Rise Time: Unipolar output, 80 nsec. Bipolar output, 100 nsec.

Maximum Amplifier Bandpass: Within 3 dB from 700 Hz to 4.3 MHz, using no pulse shaping.

Nonlinearity: Within <0.1% from 200 mV to 10 V.

Temperature Stability: Gain shift <0.015%/°C, 0 to 50 C.

Time Constant Accuracy: $\leq \pm 2\%$ of indicated value.

Controls.

Input Attenuator: Selects an attenuation factor to compress the input amplitude and affect the overall gain; factors are 1, 2, 5, 10, 20, and 50.

Coarse Gain: 3-position switch selects a relative gain factor of X1, 3, or 9.

Fine Gain: Single-turn potentiometer selects a relative gain factor continuously through the range of X1 through X3.

Integration: 8-position switch selects an integration time constant of 0.1 through 10 μsec or Out.

Differentiation: Dual concentric 9-position switch selects either single or double differentiation; each section selectable separately as D.L. (delay line), differentiation time constant of 0.1 through 10 μsec, or Out. Standard delay line provides an output pulse width of 0.8 μsec.

Input.

Input: Type BNC connector on front panel accepts either positive or negative input pulses for shaping and amplification; maximum input without attenuation, ± 2.5 V; Z_{in}, 125Ω.

Outputs.

Unipolar Output: Two each type BNC connectors on front panel; $Z_o \sim 1\Omega$ or 93Ω; linear output range 0 to +10 V; +12 V max.

Bipolar Output: Two each type BNC connectors on front panel; $Z_o \sim 1\Omega$ or 93Ω; linear output range 0 to $\pm$ 10 V; ± 12 V max.

Preamp Power: Rear panel Amphenol 17-10090 connector wired to provide operating power from the Bin and Power Supply to the Bin and Power Supply to the mating Ortec preamplifier, includes +12, -12, +24, and -24 V. Also includes a provision to permit the preamplifier signal to be accepted through the same cable and connector in lieu of the standard Input BNC.

Weight (Net). 4.3 lb (1.95 kg)

Dimensions. Standard triple-width module 4.05 by 8.714 in. (10.3 x 22.1 cm) per TID-20893 (Rev.).

2.15.4 435A Active Filter Amplifier

The 435A Active Filter Amplifier is a high-resolution, stable, wide-range amplifier. It is well suited for use with semiconductor detectors, scintillation counters, and ionization chambers. Pole-zero cancellation (adjustable) provides

overload performance (X1000 at maximum gain). It is adjustable to match the decay time of any commercially available preamplifier.

Specification

Inputs: Either positive or negative inputs are accepted. In addition, both the front-panel input and a rear-panel differntial input can be used in a differential mode to reduce common-mode (ground loop) noise by a factor of 200:1.

Signal Processing: Active filter network produces a semi-Gaussian pulse shape with the unipolar peak amplitude at 1.5 μsec and the bipolar peak at 1.1 μsec. Bipolar zero crossover is at 2.5 μsec. Coarse and fine gain controls provide gain selection of 770:1. Counting rate specifications are as follows: With a 50,000-count/sec ^{137}Cs background, the gain shift is <0.25%, and the resolution spread FWHM of a pulser peak is <0.5%. Integral non-linearity is $\leq \pm 0.075\%$ over the specified linear range.

Outputs: Prompt and 2-μsec delayed outputs, unipolar or bipolar (0 to 10 V). Crossover walks is ±2 nsec for 10:1 dynamic range with 1-μsec bipolar shaping.

2.15.5 Suitability Analysis

CONSTRUCTION. Counter is made up of four NIM modules installed in a NIM bin with its rear-mounted power supply. Packaging is typical of NIM modules--a single printed circuit board and ancillary electronics are packaged in a given module. The all aluminum module slides into the bin on tracks. Each module is secured at the front by thumb screws. A single connector at the rear connects the NIM module with the power supply and signal transmission paths. Poor volumetric efficiency. (Figure 2.15-2).

	Disposition: Accept	Disposition: Verify	Disposition: Unaccept
MATERIALS			
Aluminum			
TFE wire insulation			
Plastic knobs			
Fiberglass phenolic circuit boards			
Glass status lamps			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
NIM bin has heavy cantilevered load from rear-mounted power supply (see Figure 2.18-3 for typical installation)			X
Circuit boards can deflect in existing installations.			X
Wiring unsupported at terminals (see Figure 2.15-2)			X
Parts on circuit boards are subject to lead fatigue			X
ELECTRICAL POWER			
103 to 129 v ac or 210 to 258 v ac, 50 to 65 Hz 72 watts	X		
Modules use ± 12 or $\pm$ 240 from power supply			
DATA MANAGEMENT COMPATIBILITY			
0 - 5 v logic, analog output	X		
EMI SUSCEPTIBILITY AND RADIATION			
Low current outputs. 4π shielded.	X		
Chassis and signal ground isolated	X		
FLAMMABILITY			
Plastic knobs		X	

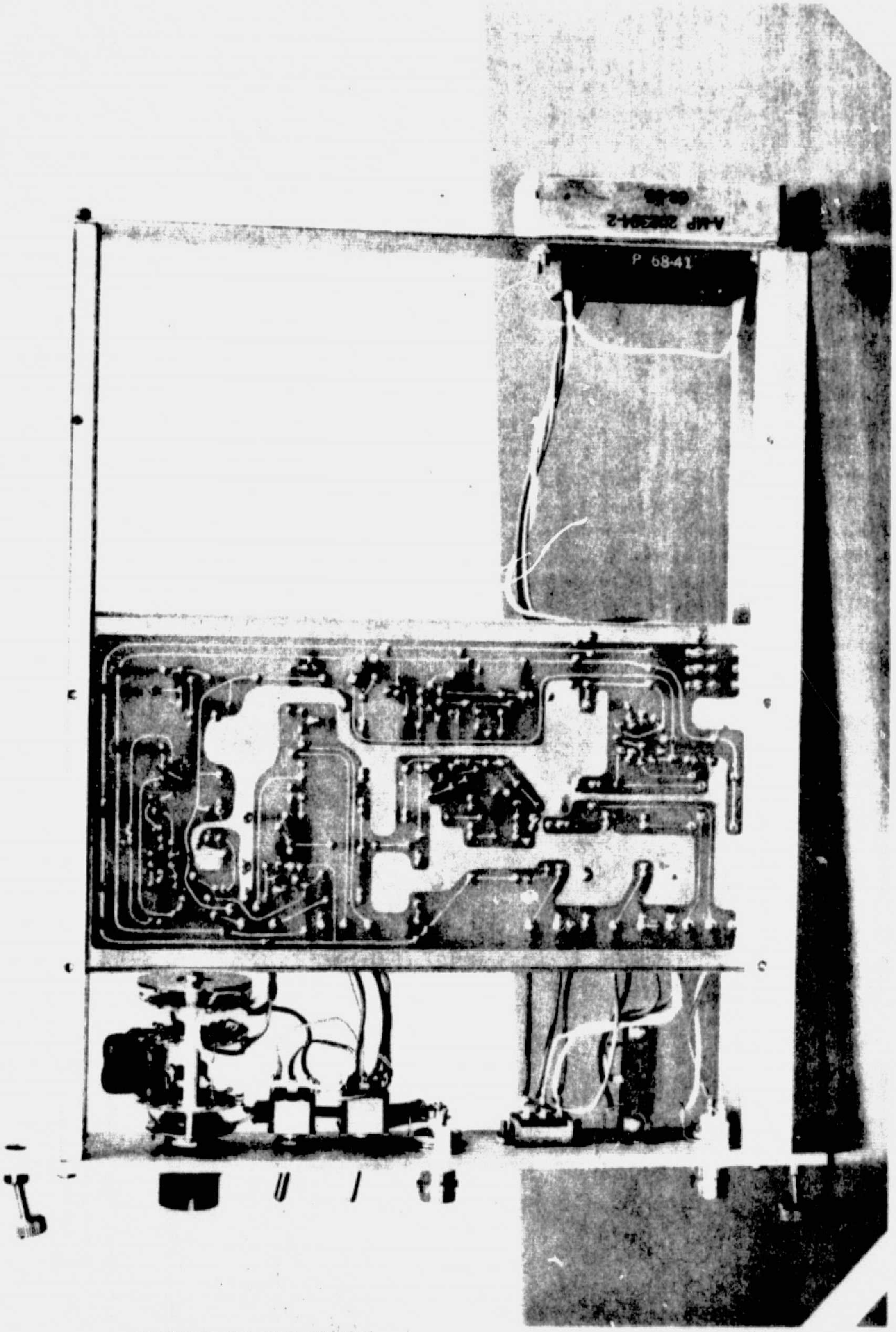


Figure 2.15-2. Wiring Unsupported at Terminals

	Disposition		
	Accept	Verify	Unaccept
CONTAMINATION GENERATION			
Exposed 1/4" status lamp types on 410 module could result in glass particles if broken.			X
ATMOSPHERE			
0 - 95% relative humidity	X		
AMBIENT TEMPERATURES			
0 to 50 C	X		
EQUIPMENT COOLING			
Vented for forced air convection	X		
ZERO-G EFFECTS			
No g dependent functions	X		
OPERABILITY			
Knobs, switches, connectors, and handles are exposed to bodily contact			X

2.15.6 Modifications

Construction

Shatterables. Fabricate and install clear cover over status bulbs on front panel of Multimode Amp per Figure 2.15-3.

Protrusion Protection. Install protection rails on rack cabinet per paragraph 12.0 of Design Guidelines.

Vibration.

1. Install cable tie-wraps as required
2. Encapsulate (conformally) printed circuit boards per paragraph 3.0 of Design Guidelines
3. Install vibration-proof fasteners where required and apply epoxy adhesive to adjustment screws per pagraph 6.0 of Design Guidelines
4. Stake 10 knobs
5. Secure 4 printed circuit boards to prevent oil-canning per paragraph 11.0 of Design Guidelines

Fabricate tapered pin rack mounted support per paragraph 1.0 of Design Guidelines.

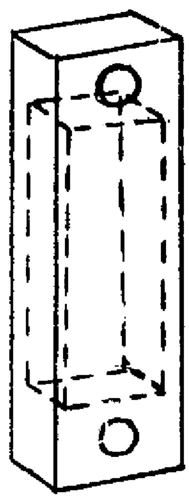
Materials Usage

1. Replace plastic knobs with those fabricated from Vespel
2. Provide 150-hour offgas bakeout.
3. Replace 10 knobs with metal or Vespel

2.15.7 Cost Analysis

Modification

Basic Cost		\$ 3,420
Modification Cost		
Fabrication	\$ 2,259	
Engineering	7,250	
Test	2,944	
Documentation	2,160	
Program Management	745	
Total Modification Cost		\$ 15,358
Total Cost		\$ 18,778



MAKE FROM CLEAR LEXAN

Figure 2.15-3. Status Bulb Cover - Counter Assembly

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME Ortec Counter ASSY NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	EXPD.	COST $ MAT'L	LABOR	TOTAL
		Fab. & Install Lexan	2	2.00	.50	.20				2.50		
		Fab. Protrusion Protection	2	2.00		.20				10.00		
		Install Tie Wraps - Cables	10		1.00	.10				5.00		
		Conformal Coat PCB DG 310	4		5.00	1.00				12.00		
		Replace Hardware (x25 each)	125							31.25		
		Secure Adjustment Screws	AR		1.50	.15				2.00		
		Secure Knobs	10		1.00	.50						
		Fab. Vespel Knobs	10	10.00		1.[illegible]				250.00		
		150 Hour Bake Out						16.00		500.00		
		Fab. Rock Mount	2	3.50	1.00	.20				22.50		
		Fab. PCB Supports	4	2.00	.40	.20				1.40		
		Other Support Required				12.00	24.00	8.00	8.00			
		TOTAL HOURS		19.50	10.40	15.55	24.00	2[illegible].00	8.00	836.65		
		LOT SIZE FROM / TO — RATE										
		O.H.										
		TOTAL								836.65	1422.80	2259.00
		TOTAL										
		TOTAL										

B[illegible] INSTRUMENTS, INC.

SHEET 1 OF 1 BY STATA

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Space Division Rockwell International

SD 74-SA-0047-3

New Development

Cost	$ 209,000
Weight	6 pounds
Complexity	0.40
State-of-the-Art Factor	2
Data Source	Lunar Orbital Study Low Energy Particles

2.15.8 ECO06M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal range capability

   a. Respecify and replace 80 electronic parts

   b. Add test chambers and test time

2. Provide external interface connectors to test item to replaceable NIM level

   a. Add NIM module frame and one rear NIM connector and one front panel 25-pin connectors.

   b. Add 25 wire test harness to NIM bin wiring

   c. Add (to NIM module frame) hardmount test signal isolation PCB (10 discretes)

   d. Patch wire 5 test signals in each of 5 NIM modules to spare NIM connector pins

3. Seal the following connectors/wire junctions from moisture

   a. Four standard NIM-to-bin connectors

   b. One P/S-to-bin harness connector

   c. Five BNC external interface connectors

4. Replace PVC as follows (delta to SEEIR mods only)

   a. 50 wires (5 per each of 5 NIMS)

5. Human factors mods as follows

   a. Replace panel fasteners in each module and bins with captive 1/4 turn type (16)

   b. Add silk screen operating instructions (10 controls)

6. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

2.15.9 Delta Modification Costs

Fabrication	$ 854	
Engineering	21,068	
Test	5,391	
Documentation	2,562	
Program Management	1,494	
Total delta modification cost		$ 31,369

2.15.10 Data Sources

1. Visual examination

2. Ortec Nuclear Catalog, May 1973

2.16 pH METER

Manufacturer: Beckman Instruments, Inc.

Model No.: pHASAR I

Cost: $570

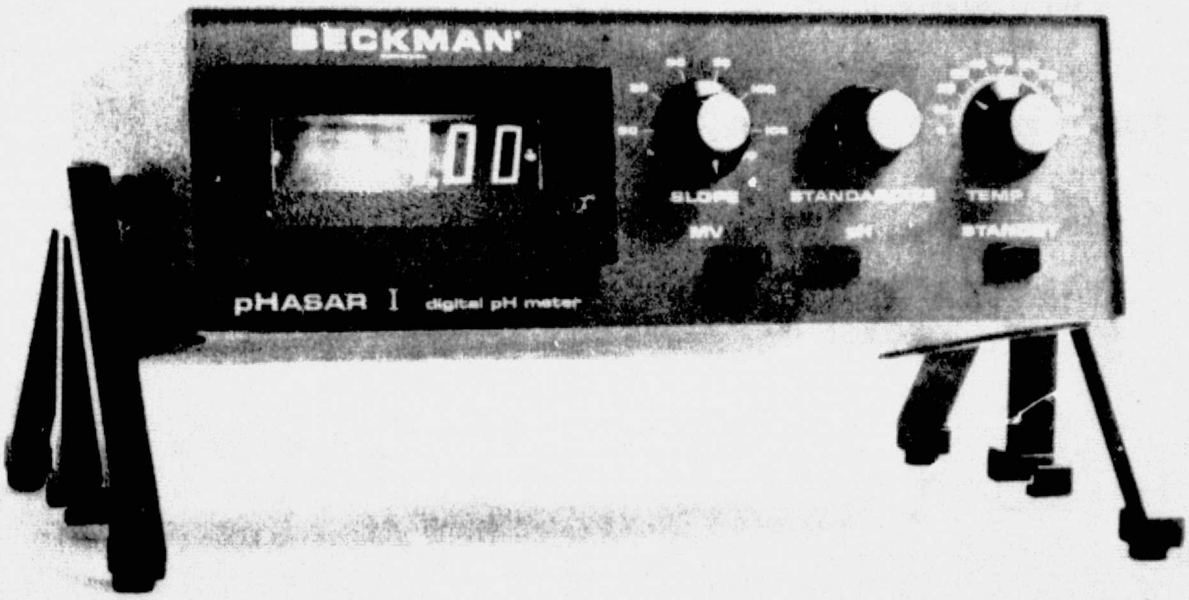

Figure 2.16-1. Beckman pHASAR I pH Meter

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2.16.1 Description

The Beckman pHASAR-1pH Meter is a digital reading, instrument for reading of pH and millivolt data over the full 0-14 pH (±1999 mv) range. It has manual temperature compensation for temperature measurements from 0 C to 100 C (and optional automatic temperature compensation). Its adjustable instrument zero point is useful when performing measurements in which the initial buffer used is a pH value other than 7.00. The pHASAR-1 is compatible with all pH and reference electrodes, the new Perma-Probe Reference Electrode and the full series of Beckman Selection and Future Electrodes.

2.16.2 Performance Characteristics

pH range	0.00 to 14.00
mv range	± 1999
Repeatability	±1 mV; ±0.01 pH
Instrument test switch	13.70 to 14.20 pH
Polarizing current	10 microamps
Zero range	6.00 to 8.00 pH
Recorder	1 to 100 mv/pH or 1 to 100 mv/100 mv
Automatic temperature compensation	0 to 100 C
Manual temperature compensation	0 to 100 C
Input bias current	Less than 0.5 pa
Standardization control	± 220 mv (3.5 pH units) minimum

2.16.3 Physical Characteristics

Dimensions	5-3/4" high (14.6 cm), 12-3/4" wide (35 cm), 8-5/8" deep (21 cm)
Net weight	5 lb (2.27 kg)

2.16.4 Suitability Analysis

	Accept	Verify	Unaccept
CONSTRUCTION. Plastic housed printed circuit board and liquid crystal module.			
Available with 19" rack kit. Judged to be inadequate for vibration and acceleration environment.			X
MATERIALS			
Glass liquid crystal display (Figure 2.16-2) Plastic housing Phenolic impregnated printed circuit board PVC insulated wire Cadmium plated chassis Plastic knobs			

Figure 2.16-2. Two Decimal Liquid Crystal

	Accept	Verify	Unaccept
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Liquid crystal display module inadequately supported.			X
Printed circuit board not adequately supported.			X
Printed circuit board components require additional support (Figure 2.16-3).			X
ELECTRICAL POWER			
Power forms: 115 V/60 Hz or 230 V/50 Hz	X		
Dissipation: 3 watts			

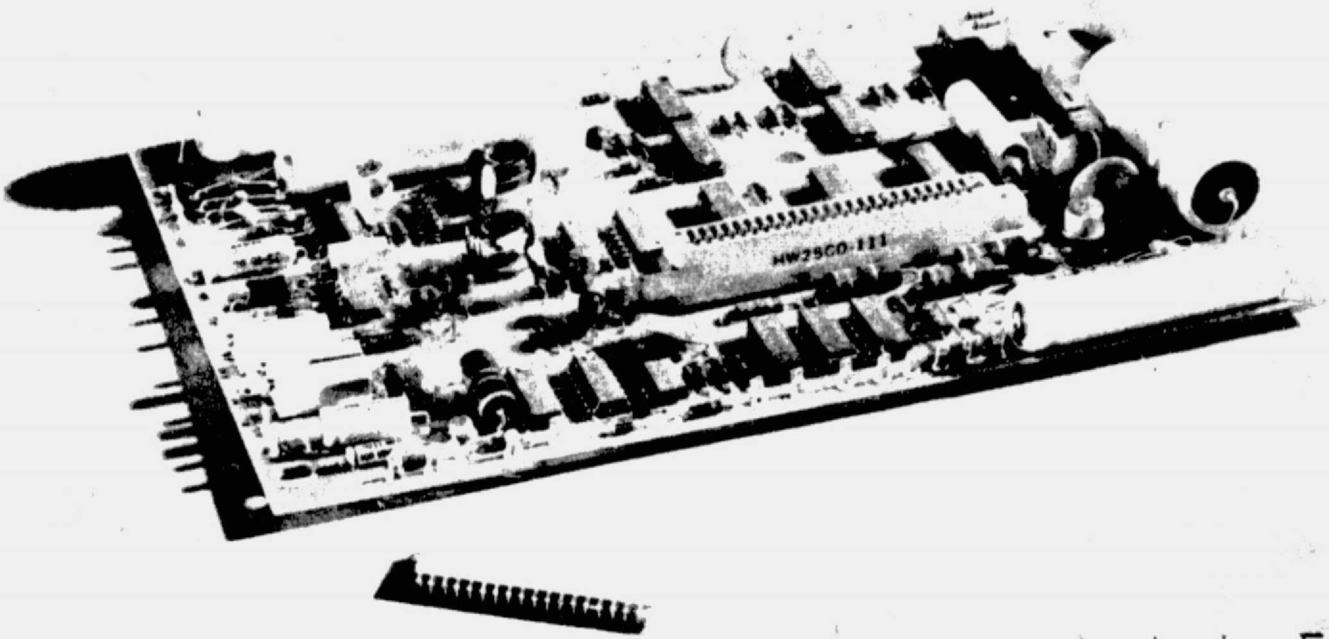


Figure 2.16-3. Circuit Board

	Disposition		
	Accept	Verify	Unaccept
DATA MANAGEMENT COMPATIBILITY			
Output interface provides 1 to 100 mv for each pH unit.			X
EMI SUSCEPTIBILITY AND RADIATION			
Not an EMI generator. May be sensitive to external EMI.		X	
FLAMMABILITY			
Plastic housing			X
Plastic knobs			X
Liquid crystal housing			X
PVC wiring insulation			X

	Disposition		
	Accept	Verify	Unaccept
TOXICITY			
Cadmium plated chassis			X
CONTAMINATION GENERATION			
Glass liquid crystal display could shatter			X
ATMOSPHERE			
85 to 95% P.R. maximum at 40 C	X		
AMBIENT TEMPERATURES			
15 to 40 C	X		
EQUIPMENT COOLING			
No cooling provisions provided. Power dissipation is so low that special provisions are not required.	X		
ZERO-G EFFECTS			
Probe operates in gravitational environment (Figure 2.16-4) by placing probe into liquid container.			X
OPERABILITY			
Protrusion protection not provided			X

Figure 2.16-4. Normal Use of pH Probe in Gravity Environment

2.16.5 Modifications

Construction

Shatterables.

1. Glass in liquid crystal readout - protect by containment. Fabricate and mount window and frame per Figure 2.16-5.

2. Probe assembly - replace glass tubes with CRES per Figure 2.16-10.

Protrusions and Edges Safety. Protection by means of recessing the instrument; see Figure 2.16-6.

19-Inch Rack Mount Capability.

1. Fabricate rack mount brackets of 0.125 thick aluminum (see Figure 2.16-6).

2. Fabricate flow cell mounting bracket per Figure 2.16-10.

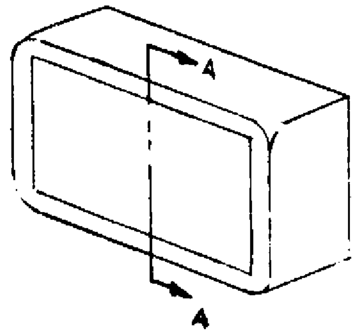
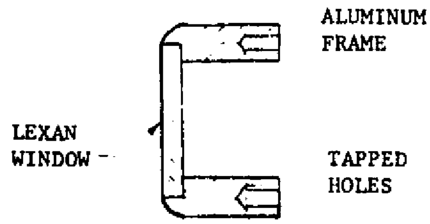


Figure 2.16-5. Liquid Crystal Containment



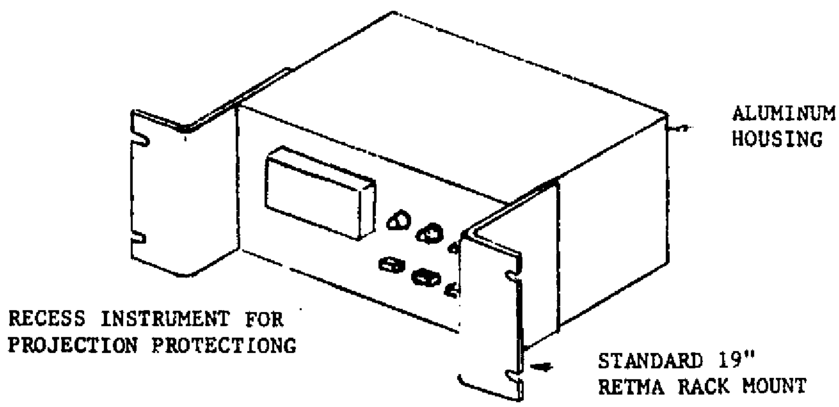


Figure 2.16-6. Rack Mount Installation

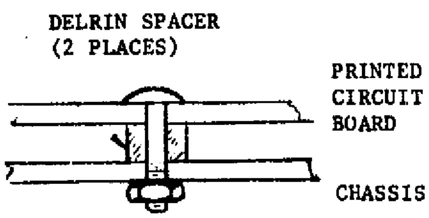


Figure 2.16-7. PCB Mounting

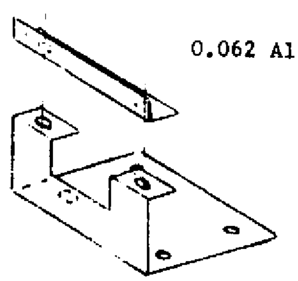


Figure 2.16-8. Clamping Bracket for Liquid Crystal Unit

Figure 2.16-9. Closed Flow Cell

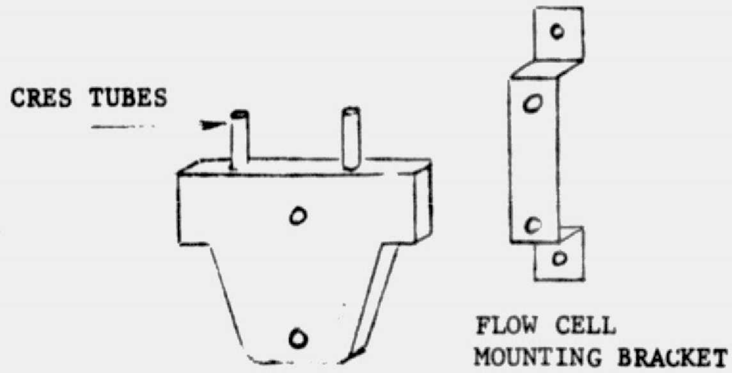


FIGURE 2.16-10. pH Meter Flow Cell Modifications

Shock-Vibration-Acceleration-Acoustics Resistance.

1. Support printed circuit board two places (see Figure 2.16-7).

2. Tie and clamp all internal wiring - approximately 12 Ty-wraps required.

3. Conformal coat printed circuit board.

4. Replace all fasteners with CRES Nylock type; estimate 50 fasteners.

5. Fabricate liquid crystal mounting bracker per Figure 2.16-8.

6. Pin knobs to their shafts.

Depressurization Hazard Suppression. Replace slip-on joints on flow cell with metal tube fittings - Swagelok or equivalent.

Materials Usage

Flaking and Peeling Resistance. Front panel to be covered with a clear, approved coating.

Concentrations of Flammable/Unidentified Materials.

1. Cadmium-plated chassis to be stripped and nickel plated.

2. Replace all plastic knobs with metal.

3. Replace plastic pushbuttons with polyimide buttons.

4. Rewire with TFE insulated wire.

5. Replace plastic case with metal.

6. Bake out 150 hours to expel volatiles.

Data System Compatibility

Add buffer amplifier to raise ± 0.7 v to $\pm$ 5 v output.

Zero-G Compatibility

Human Factors. Flow cell - must use closed cell (Figure 2.16-9).

Functional Operation. With closed-cell electrode, assembly will function in zero-g.

2.16.6 Cost Analysis

Modification

Basic Cost		$ 654
Modification Cost		
Fabrication	$ 2,197	
Engineering	9,586	
Test	5,888	
Documentation	2,160	
Program Management	946	
Total Modification Cost		$ 20,777
Total Cost		$ 21,431

New Development

Cost	$ 85,000
Weight	1.5 pounds
Complexity	1.00
State-of-the-Art Factor	3
Data Source	Beckman Apollo pH Analyzer

2.16.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal capability
   a. Respecify and replace 10 electronics parts for vacuum/thermal
   b. Add test chamber and test times for qualification and acceptance
2. Provide connector interface to test item to replaceable assembly level
   a. Add a 25-pin test connector to interface panel
   b. Add a 15-wire test harness to 3 assemblies
   c. Add a hardmounted test signal isolation PCB (6 discretes)
3. Seal the following connectors/wire junctions from moisture
   a. Two internal PCB connectors (printed PCB pins)
   b. Three input/output jacks (phono type)
4. Replace PVC as follows (delta to SEEIR mod)
   a. 50 loose wires

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MANUFACTURING COST ESTIMATE

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ASSEMBLY NO. ______ ASSEMBLY NAME PH Meter (Beckman Phasar) NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	COST $ MAT'L	LABOR	TOTAL
		PART ONE									
		Fab. & Mount Lexan	1	50	50	10			2 00		
		Fab. Aluminum Frame	1	2 50		10			5 00		
		Fab. Cres Tubulations&Install	2	2 25		25			1 00		
		PCB Support - Spacers	2	50	25	10			30		
		Ty Wrap Wiring Replacers	12		1 00	10			1 44		
		Conformal Coat PCB	1		1 20	10			5 00		
		Fab. Rock Mount Fabs.	2	1 00		10			6 00		
		Modify Case for Mount		1 00		10					
		Fab. Flow Cell Mount Bracket		1 00		10			2 50		
		Replace Fasteners w/SS NYLOC	50		8 00	50			10 00		
		Fab. Mounting Bracket	1	2 00		15			4 50		
		Replace Fittings	2		80	10			18 00		
		Clear & Mask Overspray Front Panel	1						25 00		
		Strip & Replate Chassis	1						25 00		
		Replace Knobs w/Fabbed Metal	3	3 00		15			9 00		
		Replace PB's w/Vespel Fabbed	3	3 00		15			75 00		
		Remove & Rewire w/TFE (x40)			12 00	1 00			6 00		
		Cut & Screen Vent Ports	3	6 00		60			3 00		
		Buffer Amplifiers			8 00	1 00			57 00		
		TOTAL HOURS									

LOT SIZE FROM	TO	RATE
		O.H.
		TOTAL
		TOTAL
		TOTAL

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Space Division Rockwell International

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME PH Meter (Beckman Phasar) NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	EXPD.			COST $ MAT'L	LABOR	TOTAL
		PART TWO - Required to Perform the Above												
		Complete Disassembly			4 00			4 00						
		Test & Recalibrate				6 00	8 00							
		Other Support						4 00	6 00					
		Pin Knobs to Shafts	3	50		10						50		
		150 Hour Bake Out						16 00				500 00		
		TOTAL HOURS		23 95	27 75	9 80	8 00	24 00	6 00			700 24		

Beckman INSTRUMENTS, INC.	LOT SIZE FROM	TO	RATE									MAT'L	LABOR	TOTAL
			O.H.											
			TOTAL									700 24	1346 53	2196 87
SHEET 2 OF 2 BY STATA			TOTAL											
			TOTAL											

Space Division
Rockwell International

5. Human factors mods as follows

   a. Add silkscreen operating instructions to panel (6 controls)

   b. Redesign for ease of replacement of circuit board and liquid crystal display

6. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

2.16.8 Delta Modification Costs

Fabrication	$ 396
Engineering	9,826
Test	5,170
Documentation	2,562
Program Management	898

Total delta modification cost $ 18,852

2.16.9 Data Sources

1. Visual examination of pHASAR I

2. Bulletin 7147. The Beckman pH Catalog

2.17 POWER SUPPLY

Manufacturer: Sorensen Div. of Ratheon Co.

Model No.: 40-50

Cost: $ 4200

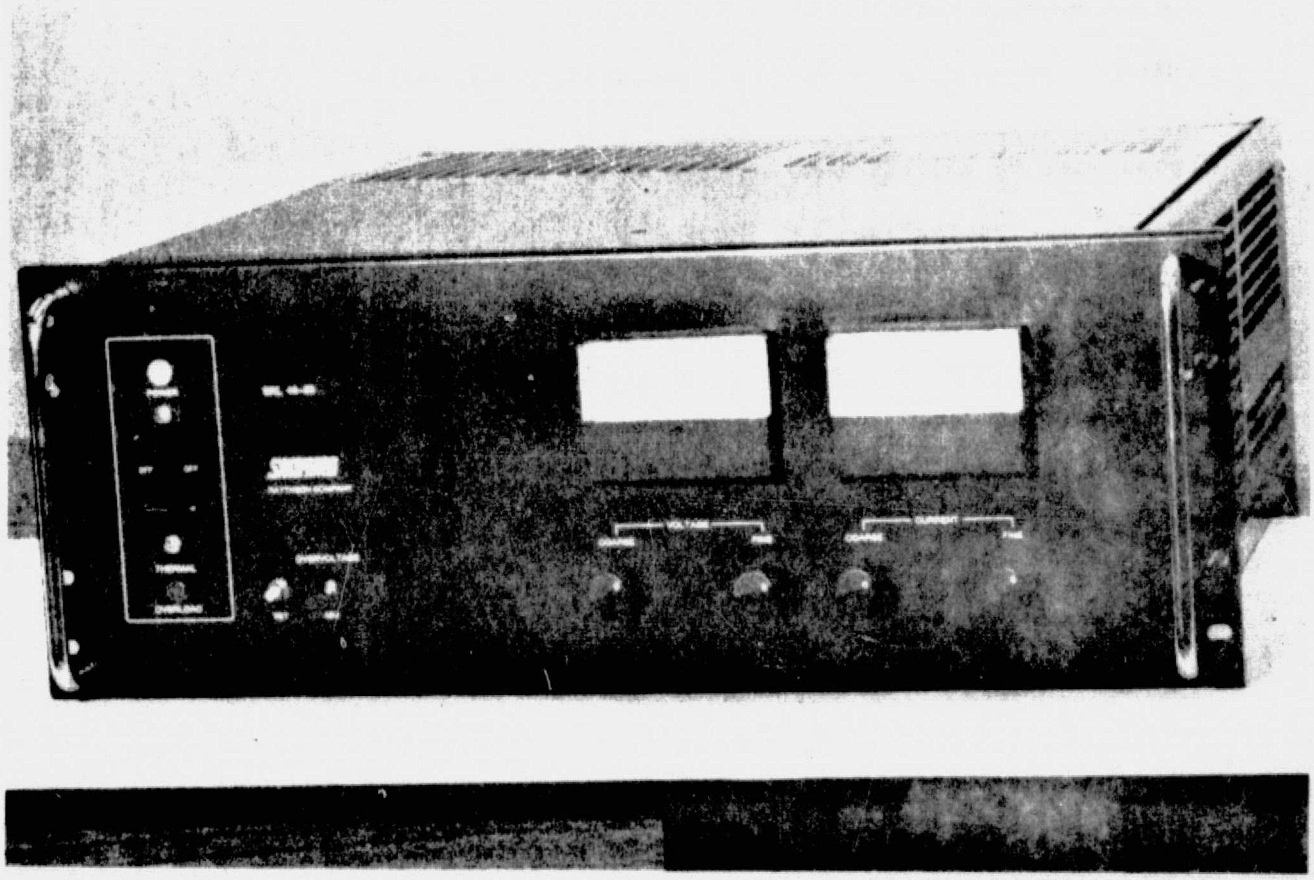

Figure 2.17-1. Sorensen Power Supply Model 40-50

2.17.1 Description

The Sorensen SRL series power supplies are low voltage, regulated solid-state DC power supplies for systems and laboratory use. The unit pictured (Figure 2.17-1) is model SRL 40-50. It is larger than the model SRL 40-R which was selected for analysis, but does reflect the construction practices used on this type of power supply.

2.17.2 Performance Characteristics

Remote Sensing: 1 volt per load lead (maximum allowable)

Series Operation: Up to 200 v dc output maximum

Parallel Operation: 3 units maximum in parallel

Output Voltage Turn-On/Turn-Off Overshoot: None

Output Current Turn-On/Turn-Off Overshoot: None

Overload/Short Circuit Protection: Cross over to current mode or cross over to voltage mode

Overvoltage Protection: 10 microsecond crowbar

Output Power				Constant Voltage Mode					Constant Current Mode		
	Current (Adc)				Ripple (PARD)					Ripple[3] (PARD)	
Voltage (Vdc)	55°	60°	71°C	Regulation[1]	rms (10 Hz to 7 MHz)	p – p (7 Hz to 25 MHz)	Resolution (Typ.)	Transient Response Time (Typ.)[3]	Regulation[1]	rms (10 Hz to 7 MHz)	Resolution (Typ.)
0-40	12	10.5	8	.01% or 2mV[2]	300μV	20mV	5mV	150μs	.02% + 4mA	1mA	1.8mA

Drift[4] (Typ.)		Programming Constants			
		Voltage Mode[5]		Current Mode	
Voltage (%)	Current	Ohms (±.5%)	Volts	Ohms (±10%)	Volts
.025% +500μV	.03% +3mA	200Ω/volt	1 volt/volt	80Ω/Amp	80mV/Amp

2.17.3 Physical Characteristics

Weight: 64 pounds (29 kg)

Dimensions: 5-1/4" high x 19" wide x 16-1/8" deep
(13.4 x 48.2 x 41 cm)

2.17.4 Suitability Analysis

	Disposition: Accept	Disposition: Verify	Disposition: Unaccept
CONSTRUCTION. Unit is a heavy, all metal rack-mounted package. Three heavy iron core transformers make up the bulk of the unit's weight. Supplementary rack support required. Nine large electrolytic capacitors are mounted to the chassis. (See Figure 2.17-2)			X
MATERIALS			
Aluminum			
Iron			
PVC insulated wire			
Plastic meter faces			
Plastic knobs			
Plastic covers on electrolytic capacitors			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Components mounted on leads			X
Circuit board requires stiffening			X
Power resistors mounted on leads			X
ELECTRICAL POWER			
105 - 125 v ac, single phase, 47-53/57-63 Hz	X		
EMI SUSCEPTIABILITY AND RADIATION			
Meets MIL-1-6181D			
Input and output isolated from chassis	X		
High current, 60 cycles may need copper shield		X	
NOISE GENERATION			
Fan noise not measured		X	
FLAMMABILITY			
Plastic knobs		X	
Plastic meter faces		X	
PVC wire insulation			X

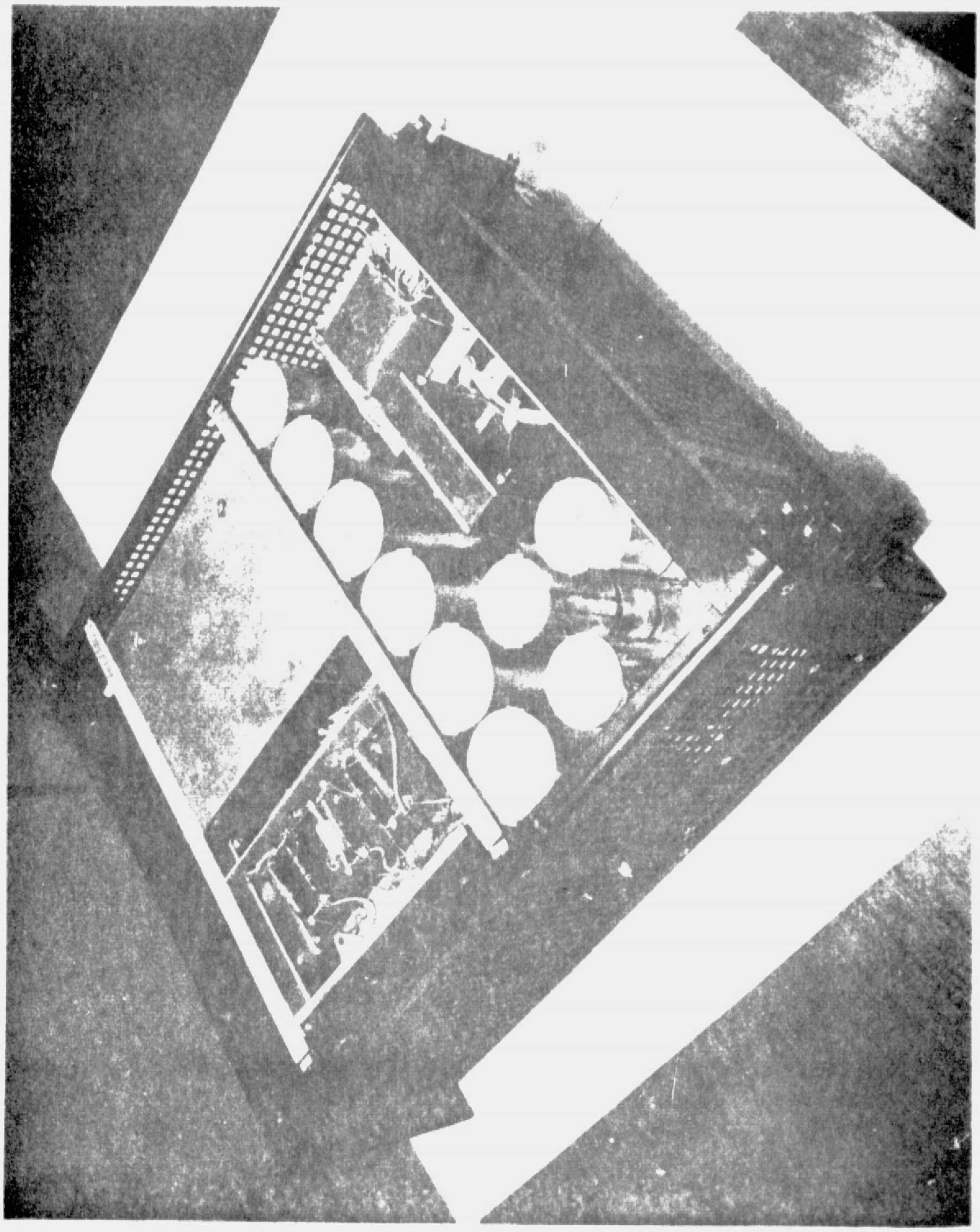

Figure 2.17-2. Chassis-Mounted Electrolytic Capacitors

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	Disposition		
	Accept	Verify	Unaccept
ATMOSPHERE			
Compatible with Spacelab	X		
AMBIENT TEMPERATURES			
Operating 0 to 71 C	X		
Non-operating -65 to 85 C			
EQUIPMENT COOLING			
Natural convection			X
Air scopp required, or rear panel to assure ventilation of circuit board for 40-12 unit			X
ZERO-G EFFECTS			
No gravity dependence	X		
OPERABILITY			
Rounded handles too small in diameter, protrusion protection required.			X

2.17.5 Modifications

Construction

9G Mounting/Integrity. Add tapered-guide pin assembly to the lower edge of rear panel (ref. Figure 5 of Design Guidelines). Inside the rack-mount cabinet install guide rails with guide pin receptacles.

Shock and Vibration.

1. Add metallic or non-metallic standoffs to rear printed circuit board as required to prevent oil-canning (ref. Figure 6 of Design Guidelines).

2. Secure six power resistors (upper right central area) to panel with spring clips (ref. Figure 3 of Design Guidelines).

3. Add terminal boards in three locations (refer to Figure 2.17-3).

4. Secure screws and knobs with positive locking features.

Materials Usage

1. Remove transparent plastic coverings of large electrolytic capacitors, replace with suitable material.

3. Replace 30 wires with TFE insulated wire.

3. Provide 150-hour bakeout for outgassing.

4. Conformally coat one circuit board.

Thermal Compatibility

Cooling vent to be provided on rear panel for heat-finned transistor on rear circuit board (see Figure 2.17-4).

2.17.6 Cost Analysis

Modification

Basic Cost		\$ 4,822
Modification Cost		
Fabrication	\$ 1,996	
Engineering	7,360	
Test	2,944	
Documentation	2,160	
Program Management	723	
Total Modification Cost		\$ 15,183
Total Cost		\$ 20,015

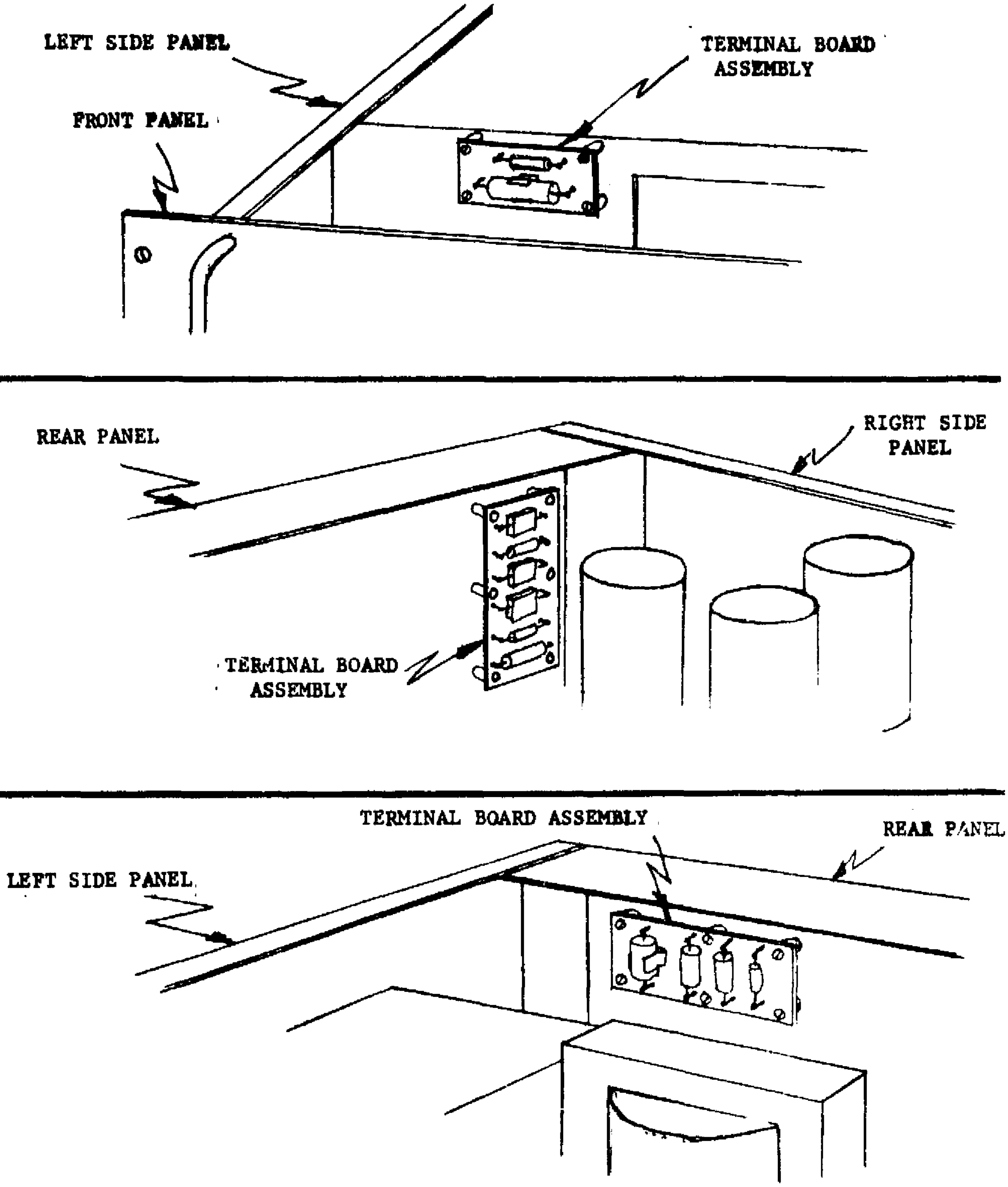

Figure 2.17-3. Terminal Board Assemblies

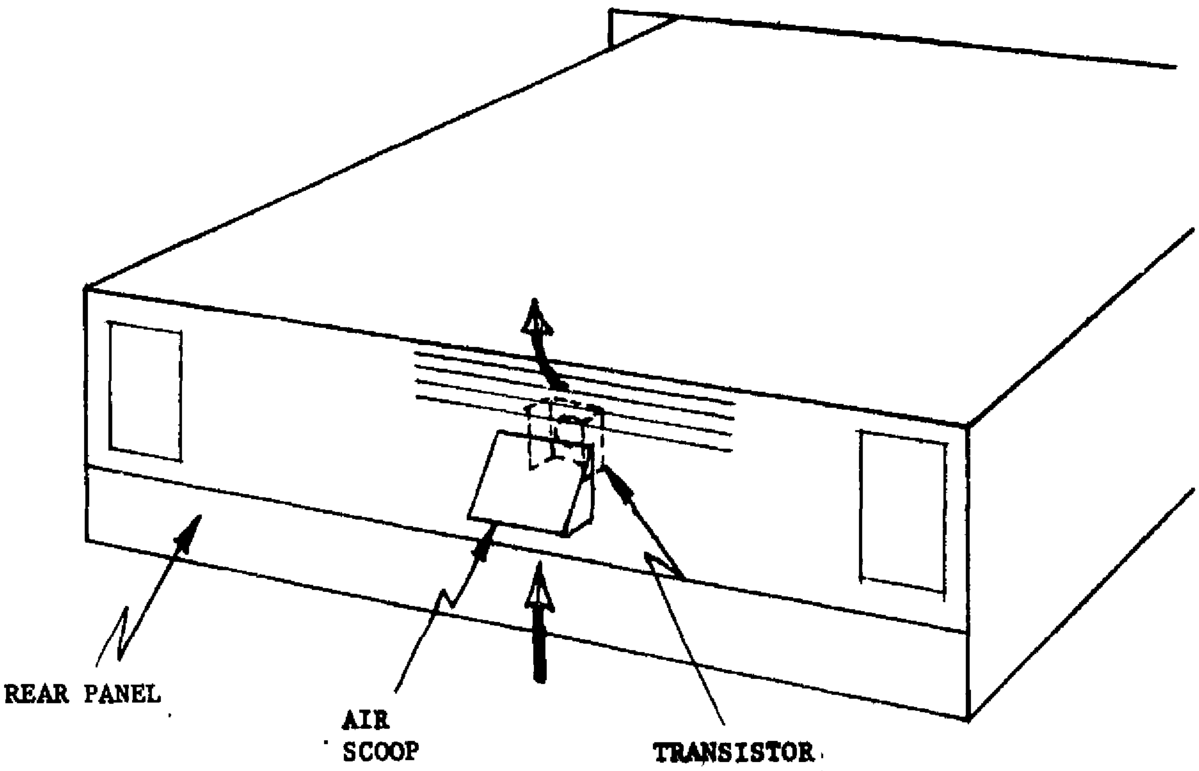

Figure 2.17-4. Air Scoop - Heat-Finned Transistor

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ________ ASSEMBLY NAME Power Supply - Sorensen SRI 40-50 NEXT ASSY NO. ________ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD			MAT'L	LABOR	TOTAL
		Fab. GUide Pin Assy and Install		1 00		25			2 00				15 00		
		PC Board Standoffs		50		10			1 00				3 00		
		Power Resistors Spring Clips	6	50		10			1 00				3 00		
		Fab. & Install Terminal Brds	3	1 00		25			3 00				15 00		
		Vibration Proof Screws			20 00	5 00							30 00		
		Remove & Replace Capacitor Coverings	9			25			4 50				10 00		
		Disassemble & Doc. for Above						6 00	6 00						
		Remove Replacer wires w/TFE	25		3 75	1 00							8 00		
		Reassemble & Test				4 00	4 00	2 00	8 00				25 00		
		150 Hour Bake Out				10 00	10 00						350 00		
		System				5 00				10 00					
		Conformal Coat Circuit Board	1		1 00	1 00		1 00	50				2 00		
		Fab. & Install Heat Vent		50		10			1 00				5 00		
		TOTAL HOURS		3 50	24 75	12 05	19 00	19 00	27 00	10 00			466 00		

LOT SIZE FROM	LOT SIZE TO	RATE	MAT'L	LABOR	TOTAL
		O.H.			
		TOTAL	466 00	1529 54	1995 54
		TOTAL			
		TOTAL			

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SD 74-SA-0047-3

New Development

Cost	$ 26,000
Weight	50 pounds
Complexity	0.20
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter EPS

2.17.7 EC006M De_ta Modification Requirements Summary

1. Provide non-operating vacuum capability
   a. Respecify and replace 25 electronic parts
   b. Add vacuum test chambers and test time for qual and acceptance
2. Provide external test connector capability to test item to replaceable level
   a. Add one 25-pin external interface connector
   b. Add one 25-wire test harness
   c. Add one hardmounted test signal isolation circuit board (10 discretes)
3. Seal the following connectors/wiring junctions against moisture
   a. Two Kulka terminal strips on external rear panel
   b. Four internal connectors (no printed pins)
4. Replace PVC as follows (delta over SEEIR mods)
   a. 200 loose wires and part lead spagetti sleeving
5. Human factors mods as follows
   a. Redesign for ease of maintenance into 4 replaceable modules (2 per channel)
   b. Add captive 1/4-turn panel fasteners (4 places)
   c. Add silk screen operating instructions on panel (7 controls)
6. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

2.17.8 Delta Modification Costs

Fabrication	$ 719
Engineering	12,512
Test	5,373
Documentation	2,562
Program Management	1,058

Total delta modification cost $ 22,224

2.17.9 Data Sources

1. Visual examination
2. Sorensen 74a Short Form Catalog. Ratheon Co.

2.18 NIM POWER SUPPLY

Manufacturer:	Power Designs Inc.
Model No.:	AEC-320
Cost:	$ 275

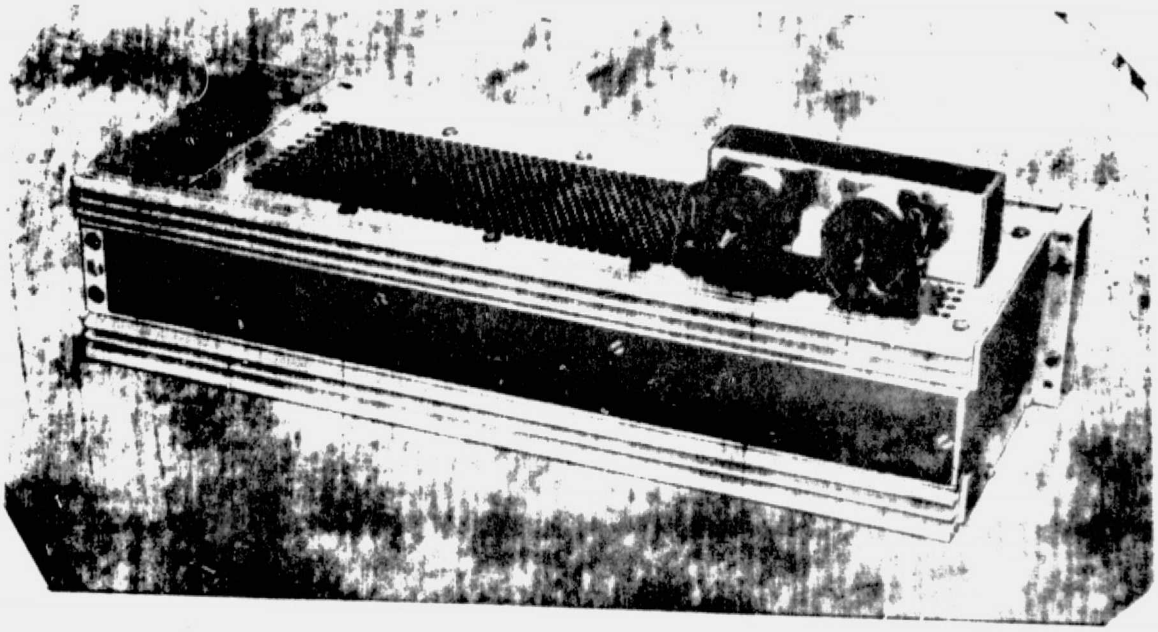

Figure 2.18-1. Power Design NIM Power Supply

2.18.1 Description

This unit provides three regulated outputs: ±6 VDC at 10 amperes from either source and +12 VDC at one ampere, with a maximum supply output rating of 72 VA. Built-in over-voltage crowbar circuits protect NIM modules against damage. Power input and output routing connectors permit interbin bussing of voltages not available in the power supply.

2.18.2 Performance Characteristics

Output: ±12 VDC 0-2 amp
±24 VDC 0-1 amp

Regulation: ±0.05%

Noise and ripple less than 3 mV peak to peak

Full range voltage adjustment

Output impedance less than 0.3 ohm at any frequency up to 150 kHz

2.18.3 Physical Characteristics

Dimensions: 17" l x 3-1/2" w x 5-1/2" h (43 x 9 x 14 cm)

Weight: 16.5 lb (7.5 kg)

2.18.4 Suitability Analysis

Item	Accept	Verify	Unaccept
CONSTRUCTION. Unit is compactly constructed. Two printed circuit boards are mounted vertically with large capacitors attached by lead mountings (see Figure 2.18-2).			
When attached to rear of NIM bin it creates a heavy cantilever load which is only supported by screws on front of NIM bin (see Figure 2.18-3).			X
MATERIALS			
Glass fuses			
Iron			
Aluminum			
TFE wire insulation possibly			
Clear iridate coating over cadmium plating on dust covers		X	
Copper			
G-11 printed circuit board material			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Two lead mounted elecctrolytic capacitors			X
Four capacitors on circuit board lead mounted			X
Four capacitors are lead mounted and traverse a cutout in the circuit board			X
ELECTRICAL POWER			
117 v ac + 10%/-12%, 60 Hz ± 3	X		
EMI SUSCEPTIBILITY AND RADIATION			
Power transformer is constructed with an electostatic shield connected to the core	X		
Entire supply is enclosed with an integral metal electrostatic shield	X		
Input line is filtered	X		
FLAMMABILITY			
Printed circuit boards are flame retardent. Transformers rated to high temperature	X		
Plastic knobs			X
Unit meets highest UL flammability rating			

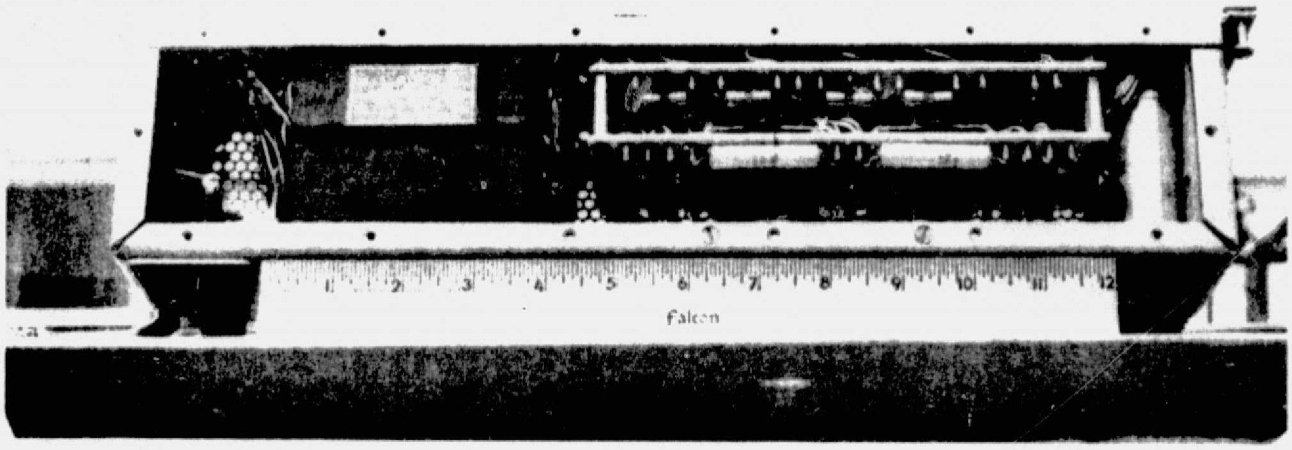

Figure 2.18-2. Interior of Power Supply

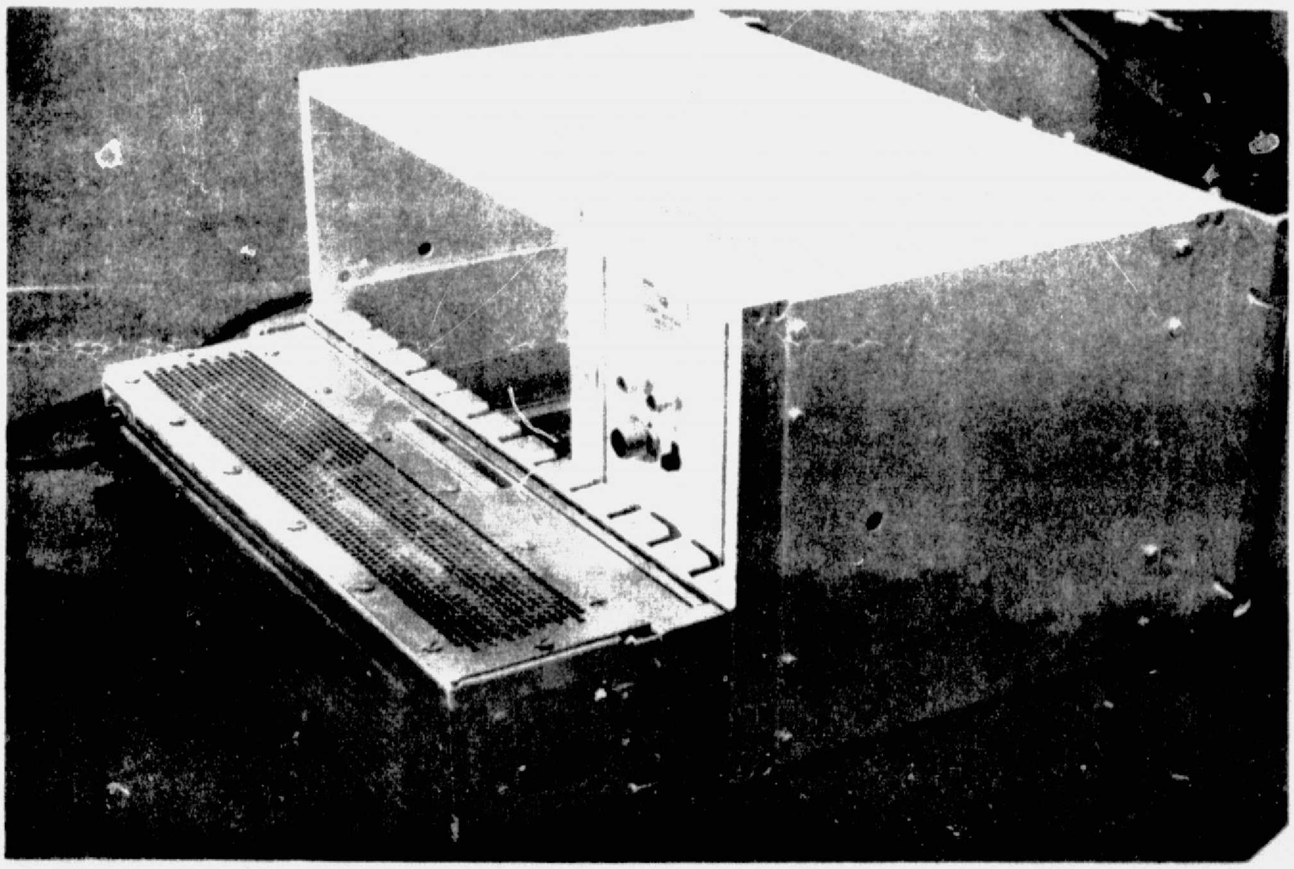

Figure 2.18-3. NIM Bin with Attached Power Supply

	Disposition		
	Accept	Verify	Unaccept
CONTAMINATION GENERATION			
Glass fuses exposed to allow potential particle escape			X
ATMOSPHERE			
Compatible with Spacelab environment	X		
AMBIENT TEMPERATURE			
0 to 50 C	X		
EQUIPMENT COOLING			
Venting openings for forced air cooling	X		
Thermal protection switch which disables power supply when safe operating temperature is exceeded	X		
ZERO-G EFFECTS			
No gravity dependent functions	X		

2.18.5 Modifications

Construction

Shatterables. Due to glass components (open "auto" fuses), cover inside of a venting with metallic fine-mesh screen.

9-G Mounting. Fabricate guide pin assembly and attach to rear of unit per Figure 2.18-4. Guidel rails and guide pin receptacles to be installed in rack cabinet per Figure 5 of Design Guidelines.

Shock and Vibration.

1. Secure "hole-in-board" and end-mounted capacitors per Figure 2.18-5.
2. Clip four smaller capacitors to circuit board per paragraph 4.0 of Design Guidelines.
3. Conformally coat lower circuit board with appropriate material. Mask where required.

Material Usage

1. Provide a 150-hour bakeout to expel off-gas products.

2.18.6 Cost Analysis

Modification

Basic Cost		$ 316
Modification Cost		
Fabrication	$ 1,728	
Engineering	5,380	
Test	4,416	
Documentation	2,160	
Program Management	680	
Total Modification Cost		$ 14,364
Total Cost		$ 14,680

New Development

Cost	$ 24,000
Weight	10 pounds
Complexity	0.30
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter EPS

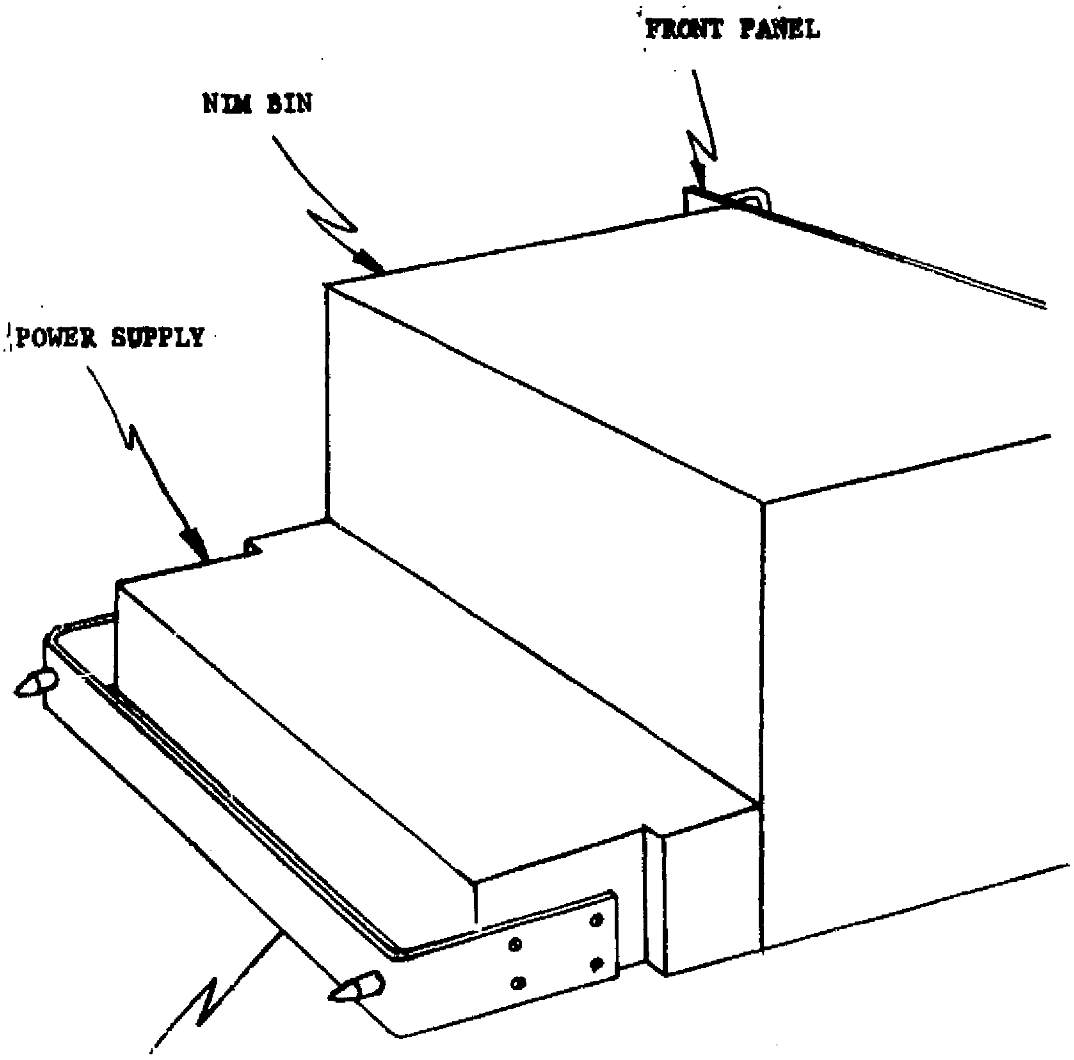

Figure 2.18-4. Guide Pin Assembly Attachment

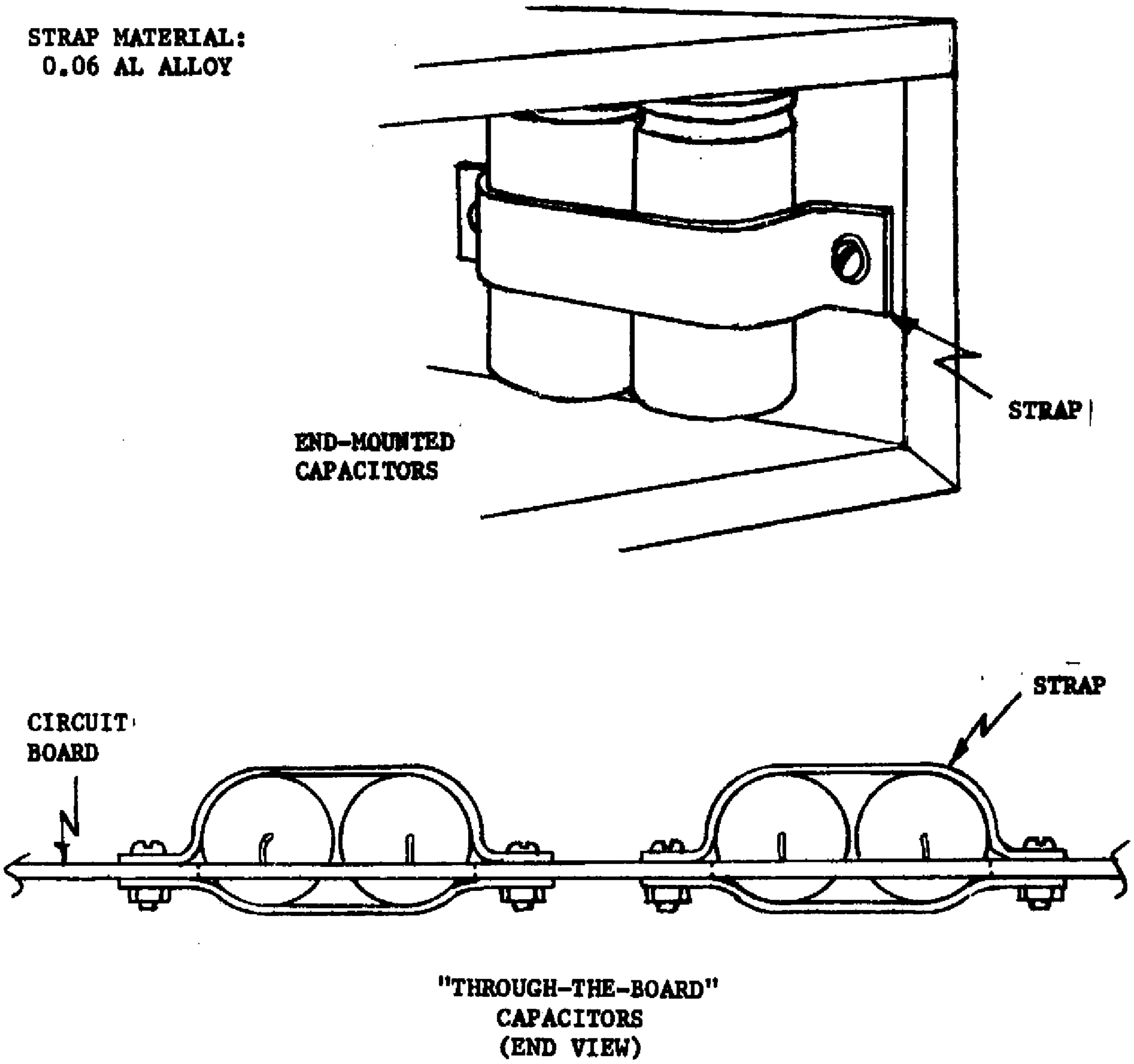

Figure 2.18-5. Capacitor Securing

MANUFACTURING COST ESTIMATE

52-23-07.1

ASSEMBLY NO. AEC-320-3 ASSEMBLY NAME NIM Power Supply-Power Design NEXT ASSY NO. ________ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	EXPD.	COST $: MAT'L	LABOR	TOTAL
		Screen Vents	AR	3 00	1 50	50		1 00		6 00		
		Fab. Guide Pin Assy		1 00	75	10				10 00		
		Fab. Rails & Receptacles		2 50	25	10				17 50		
		Secure Caps	6	2 00	1 00	25				4 50		
		Install Cap Clips to PCB	4				40			1 00		
		Conformal Coat PCB	1		1 25	20				3 00		
		150 Hour Bake Out						16 00		500 00		
		Support of Above Plus Test & Calibrate				10 00	30 00	4 00	8 00			
		TOTAL HOURS		8 50	4 75	11 15	30 40	21 00	8 00	537 00		

LOT SIZE FROM	TO		
		RATE	
		O.H.	
		TOTAL	MAT'L 537 00, LABOR 1190 77, TOTAL 1728 00
		TOTAL	
		TOTAL	

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SD 74-SA-0047-3

Space Division
Rockwell International

2.18.7 EC006M Delta Modification Requirements Summary

1. Provide nonoperating vacuum and thermal range capability
   a. Respecify and replace 15 electronic parts for thermal-vacuum
   b. Add test chambers and test time for qualification and acceptance
2. Provide interface connector to test item to replaceable assy level - none (item is lowest operational replaceable assy)
3. Seal the following connectors/wiring junctions against moisture
   a. One interface (external) connector
4. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**
5. Human factors redesigns as follows
   a. Replace mounting fasteners with 1/4-turn captive type (4)

2.18.8 Delta Modification Costs

Fabrication	$ 318	
Engineering	12,641	
Test	4,766	
Documentation	2,562	
Program Management	1,014	
Total delta modification cost		$ 21,284

2.18.9 Data Sources

1. Visual examination
2. Specification TID-20893, Rev. 3. Standard Nuclear Instrument Modules, Power Designs Model AEC-320-7

2.19 REFRIGERATOR/FREEZER

Manufacturer: Revco

Model No.: ULT 185

Cost: $ 1060

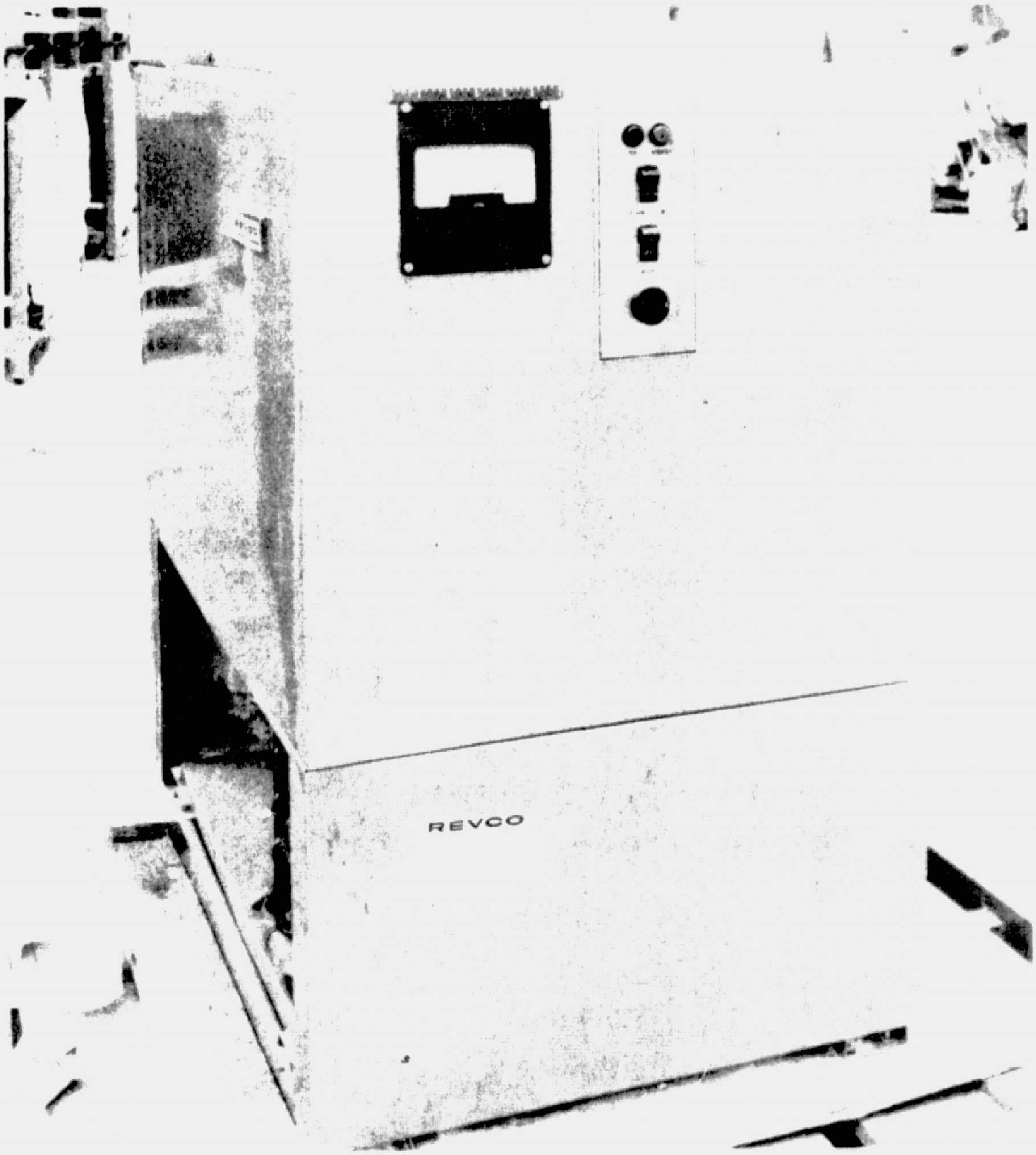

Figure 2.19-1. Revco Refrigerator/Freezer

2.19.1 Description

A fan and shell condenser dissipates heat and keeps the cabinet dry and free of rust. Condenser is tubular static, attached to inner wall of cabinet shell by welded metal strips and sealed by mastic. No liquid coolant is required. Counter Balanced Lid - Chest models have spring tension hinge which opens to 75 degrees and is counter-balanced for ease of access.

2.19.2 Performance Characteristics

Range: +20 F to -121 F (-7 C to -85 C) in 70 F (+21 C) ambient

Control Band: ±1 C

2.19.3 Physical Characteristics

Storage Capacity: 1.5 cu ft (0.041 cu.m.)

Interior: 18-3/8" wide x 12-1/2" high x 11-3/4" deep (46.7 x 31.7 x 30.1 cm), #302 stainless steel, 18 gauge, liquid tight

Exterior: 34" wide x 37" high x 24" deep (86.4 x 94 x 61 cm)

2.19.4 Suitability Analysis

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. Constructed from sheet steel. Box is not made to withstand rigorous space-type environment. Floor plate is supported by stringers on 2-foot centers. Buckling can be noted in floor plate in Figure 2.19-2. Unit is floor mounted. Freezer box has 6 inches insulation around.			
MATERIALS			
Rubber 16, 18 and 20 guage steel Zinc phosphate coating Acrylic enamel paint Fiberglass and polyurethane insulation Freon 12 Silicon sealant Glass Freon 13 Aluminum Stainless steel			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Mounting floor needs center support. Unit exhibited buckled floor from shipping.			X
Transformer mounted to side wall on end			X
Support required for condenser, fan accumulator and fans (Figure 2.19-3)			X
Motor capacitor bracket requires strengthening			X
Screws are not positively retained			X
ELECTRICAL POWER			
Available for 115, 208, or 230 V @ 60 Hz 100, 115, or 230 V @ 50 Hz	X		
DATA MANAGEMENT COMPATIBILITY			
Side mounted ink pen; circular dish recording chart			X
EMI SUSCEPTIBILITY AND RADIATION			
60-cycle power transformer and motor are not enclosed			X
NOISE GENERATION			
Literature states quiet operation		X	

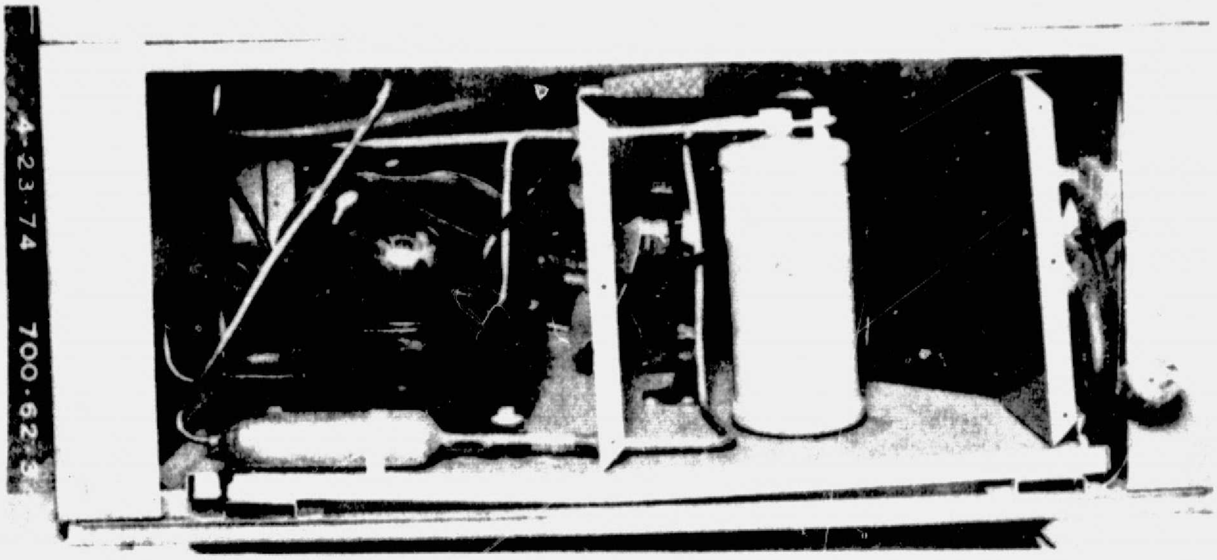

Figure 2.19-2. View Showing Refrigeration Components and Buckled Floor

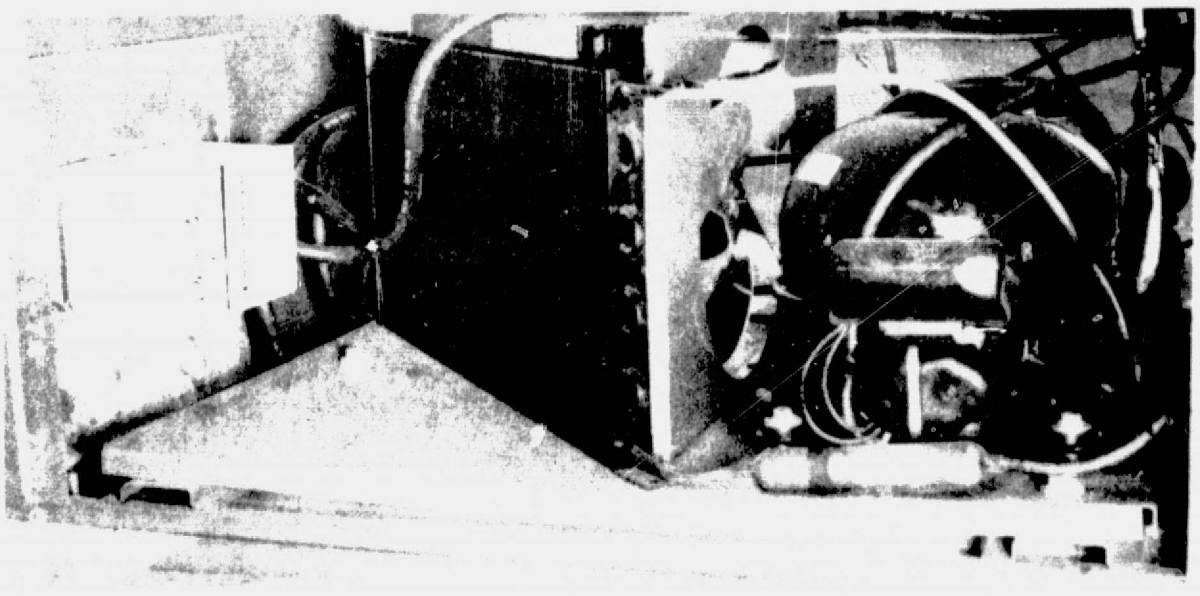

Figure 2.19-3. Condenser, Fan, and Accumulator

	Disposition		
	Accept	Verify	Unaccept
FLAMMABILITY			
PVC insulated wiring			X
TOXICITY			
Polyurethane foam			X
Mastik sealant			X
Freon 12			X
Freon 13			X
Rubber			x
CONTAMINATION GENERATION			
Baked enamel coating	X		
Fiberglass insulation			X
Glass on meter face			X
ATMOSPHERE			
Compatible with Spacelab	X		
AMBIENT TEMPERATURES			
Compatible with Spacelab	X		
EQUIPMENT COOLING			
Thermal capacity: 38 K cal/hr at -68 C in 21 C ambient			
ZERO-G EFFECTS			
Refrigeration system relies on gravity for proper operation. Under zero-g liquid will not remain in evaporator causing compressor to fail. Requires totally new development of a zero-g compatible regrigeration cylce, or must use cryogenic boiloff.			X
Proper compressor lubrication is maintained by gravity.			X
OPERABILITY			
No protrusion protection			X

2.19.5 Modifications

It was concluded that modification of this unit for operation in the Spacelab would not be cost effective. The refrigeration cycle is dependent on gravity for proper operation. The refrigerant exits in two phases, gas and liquid, in the evaporator and condenser. Only gas can leave the evaporator or damage to the compressor occurs. Only liquid can leave the condenser or the expansion valve will not function properly. Therefore, an independent refrigeration cycle must be used. A cryogenic boiloff or low temperature space radiator concept could provide the low temperature performance required. The box itself could also not be saved. It was judged to be to flimsy to survive the vibration and acceleration loads expected during flight. More rugged construction plus changeout of unacceptable materials left little of the box to be retained. Since both the box and the refrigeration cycle have to undergo complete change, it was concluded that the unit can only be obtained by custom building a unit. Revised design and modification costs have not been generated. Customer cost data is presented.

2.19.6 Cost Analysis

New Development

Cost	$ 127,000
Weight	50 pounds
Complexity	1.00
State-of-the-Art Factor	4
Data Sources	Space Station Exp. 5.13 Module 5.16

2.19.7 EC006M Delta Modification Requirements Summary

Delta requirements to meet EC006M00000A were not generated inasmuch as modification was determined to be meaningless as explained in 2.19.5 above.

2.19.8 Data Sources

1. Visual examination

2. Ultra-Low Temperature Units by Revco. Revco Inc. 1970

2.20 AMPLIFIER

Manufacturer: Neff

Model No.: 126

Cost: $390/Module

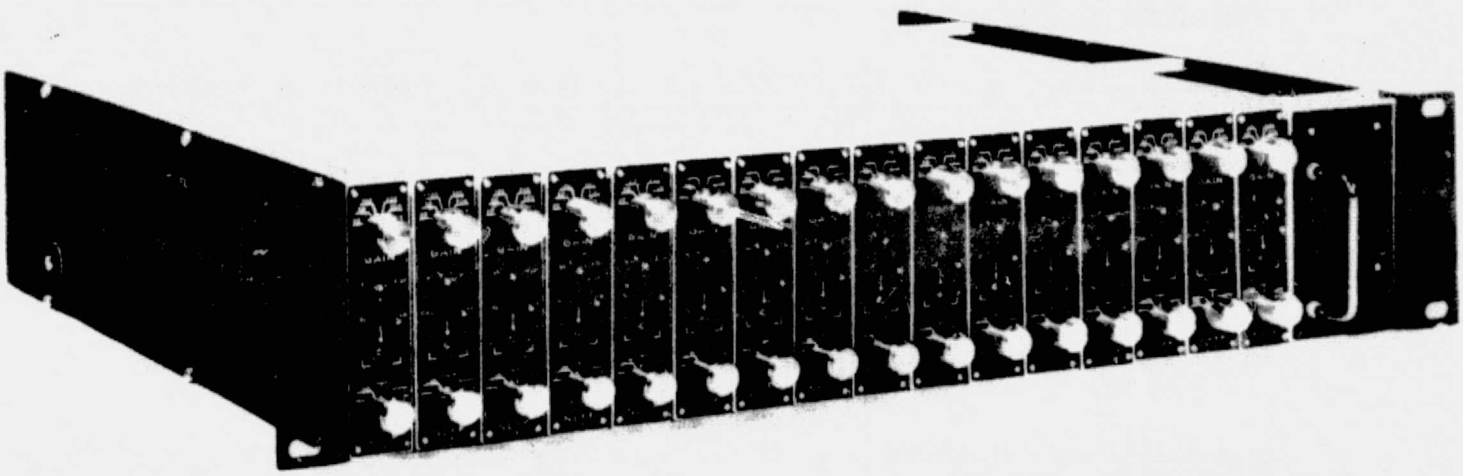

Figure 2.20-1. Two Neff Amplifiers and Power Supply in a Modular Assembly

2.20.1 Description

The Neff Model 126 differential instrumentation amplifier is designed for application in multi-channel data processing systems. The model 126 features continuous gain from 0.2 to 2500 and bandwidth DC to 50 kHz. Output multiplexer allows direct connection to data bus in multi-channel systems. Continuous output affords on-line monitoring and control capability. Switch-selectable filter is available for limited bandwidth applications.

2.20.2 Performance Characteristics

Electrical Performance

Gain. Six fixed gain steps of 20, 50, 100, 200, 500, and 1000. Variable Gain Multiplier has range of 1 to 2.5 times each gain step providing continuous gain span of 20 to 2500. Front panel switch provides selection of calibrated or variable gain. Gain range 0.2 to 2500 provided with optional attenuator.

Gain Step Accuracy. ±0.1%

Gain Stability: ±0.01% (±100 parts per million) at constant temperature, ±0.005%/°C (±50 parts per million/°C) for fixed gain steps.

Linearity. Less than ±0.01% of full scale, terminal inearity.

Optional Attenuator. Available is a front-panel switch-selectable input attenuator which extends the gain range from 0.2 to 2500 in 12 steps. Input impedance on gain 10 and below is 1 megohm.

Bandwidth. ±10% DC to 20 kHz minimum, less than 3 db down from DC to 50 kHz at all gains.

Settling Time. Amplifier settles to within ±0.1% of final value in less than 100 microseconds.

Input Impedance. 10 megohms shunted by less than 1000 picofarads, for gains 20 and above. 1 megohm shunted by 1000 picofarads for gains 10 and below, with optional attenuator.

Source Impedance. Amplifier meets all specifications with source impedances to 1000 ohms unless otherwise stated. Operation at higher impedance levels permitted. Input can be grounded or floating.

Maximum Input Voltage. Amplifier will withstand differential input voltage of ±20 volts and common mode voltage of ±20 volts.

Common Mode Rejection: 120 db minimum DC to 60 Hz with input source resistance to 350 ohms in any unbalance, at gains of 1000 or greater. 60 db plus gain in db for gains below 1000.

Common Mode Voltage. ±10 volts (20 volts peak-to-peak) to meet specifications.

Zero Stability. Less than ±5 microvolts, RTI, ±200 microvolts, RTO, at constant temperature for 30 days after 30 minute warmup for gain 20 and above. For gains below 20 with optional attenuator, ±20 millivolts, RTO, maximum.

Zero Drift. Less than ±1 microvolt/°C, RTI, ±100 microvolts/°C, RTO, for gains 20 and above. For gains below 20, with optional attenuator, ±10 millivolts/°C maximum.

Zero Adjustment. Recessed, front panel mounted multi-turn controls provide independent input and output zero adjustment.

Source Current. Less than ±2 nanoamperes at constant temperature. Temperature coefficient is ±1 nanoampere/°C maximum.

Noise. Measured with a 1K ohm signal source impedance, for gains 20 and above.

Bandwidth	Noise
Wideband	4μv rms, RTI, plus 1 mv rms RTO
10 kHz	2μv rms, RTI, plus 1 mv rms RTO
10 Hz	1μV peak-to-peak, RTI, plus 0.5 mv peak-to-peak, RTO

For gains below 20, with optional attenuator, 5 millivolts, rms, RTO, Wideband and 5 millivolts, peak-to-peak, RTO, in 10 Hz bandwidths.

Overload Recovery. Amplifier will recover to within ±0.1% of final value in less than 1 millisecond from 1000% overload.

Power Requirement. Amplifier operates from supplies contained in the Model 021 Rack Enclosure. Amplifier may be operated independently from plus and minus 20 ± 1 volt supplies with less than 100 millivolts peak-to-peak ripple.

2.20.3 Physical Characteristics

Size. Each amplifier is 14 inches in length, including rear connector, 0.92 inch in width, and 3.5 inches in height. (35.5 x 2.32 x 8.9 cm)

Mounting. Model 021 Rack Enclosure accommodates 16 amplifiers for 19-inch rack mounting and includes a line operated p[illegible]-in power supply. Amplifiers are locked in position by a unique latch which releases at the touch of a button. The Model 021 occupies 3.5 inches panel height and is 16.4 inches deep. (48.2 x 8.9 x 41.6 cm). Weight 35 pounds (15.9 kg)

2.20.4 Suitability Analysis

	Disposition: Accept	Disposition: Verify	Disposition: Unaccept
CONSTRUCTION. Sixteen amplifier modules are installed in a 19-inch rack. Each amplifier consists of a single circuit board with front controls and a real connector (Figure 2.20-2). A latch at the rear of the assembly, activated by a button on the front panel, holds each circuit board in place. Plastic tracks constrain each circuit board at top and bottom. Uses FET components.			
MATERIALS			
Plastic Fiberglass phenolic Aluminum Mylar Teflon wiring			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Vibration. Amplifier will withstand shock and vibration of normal shipping and handling of laboratory equipment.			
Power supply has two heavy transformers that cause significant loads on circuit board (Figure 2.20-3).			X
Input/output connectors can back out. No positive latching.			X
End mounted capacitors between circuit board latching mechanism (Figure 2.20-4).			X
ELECTRICAL POWER			
105 - 125 V AC or 200 - 250 V AC, 50 to 400 Hz	X		
DATA MANAGEMENT COMPATIBILITY			
Output. ± 10 volts at $\pm$ 10 milliamperes over full bandwidth at all gains. Output is protected against short circuit of any duration. Amplifier will remain stable with capactive load of 1.0 microfarad.	X		
Output Impedance. Less than 0.2 ohm in series with 100 microhenries, direct output.			
Multiplexer Output. Multiplexed output is enabled by a 3.5 to 5.0 volt signal on the control input. Output impedance is 50 ohms maximum. Off impedance is 10^{10} ohms minimum, shunted by 5 picofarads maximum.			

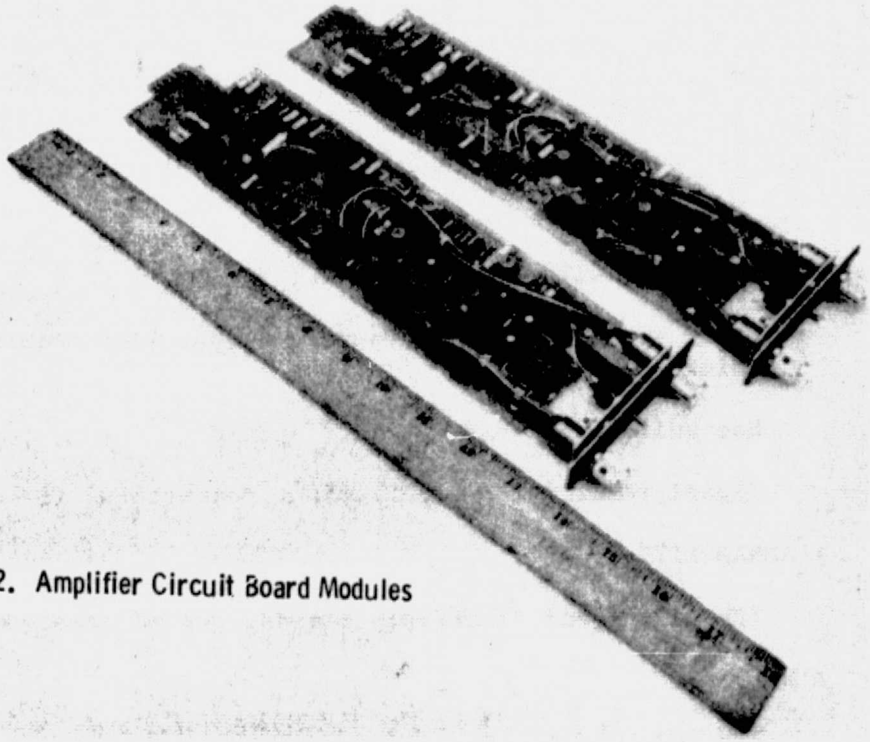

Figure 2.20-2. Amplifier Circuit Board Modules

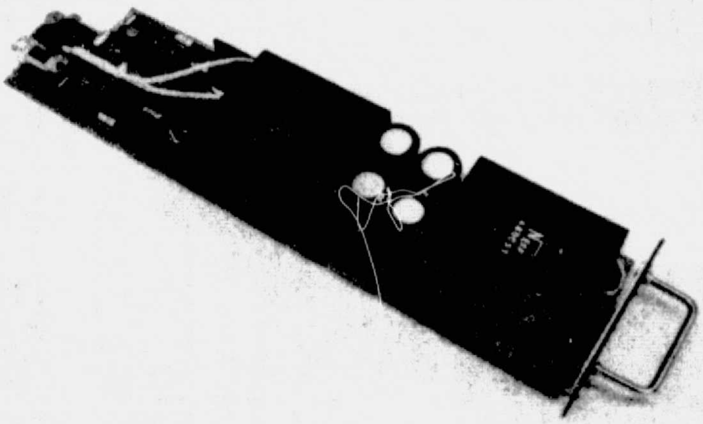

Figure 2.20-3. Power Transformer Module

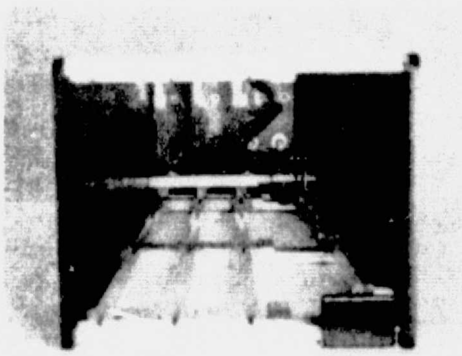

Figure 2.20-4. Module Latching Mechanism

	Disposition		
	Accept	Verify	Unaccept
EMI SUSCEPTIBILITY AND RADIATION			
Power supply potential source. Input line requires shielding.			X
Has guard input and separate shield	X		
Signal returned to input/output connectors	X		
FLAMMABILITY			
TFE wiring and fiberglass boards; sealed transformers	X		
ATMOSPHERE			
Altitude - all specifications apply for altitudes to ±20,000 feet	X		
Moisture - 90% relative humidity			
AMBIENT TEMPERATURES			
Operating temperature - amplifier will perform to stated specifications within a temperature range of 0°C to +50°C	X		
EQUIPMENT COOLING			
Installation compatible with forced air cooling in rack	X		
ZERO-G EFFECTS			
No gravity dependent functions	X		
OPERABILITY			
Handles require additional radius for protrusion protection.			X

2.20.5 Modifications

Construction

9-G Mounting.

1. Remove PC board latching apparatus.

2. Remove nylon card guides and replace with machined aluminum guides (see Figure 2.20-5). These guides serve as structural elements (top and bottom panels). To prevent oil-canning, provide vertical structural elements between top and bottom guides, so located as not to interfere with the insertion or withdrawal of modules.

3. Provide holes in front panel (top and bottom) of each amplifier and attach captive fasteners. These fasteners will secure modules to the card guide front edges.

4. The power supply front panel must be configured to provide support for the transformers and electrolytic capacitors (see Figure 2.20-6).

Shock and Vibration.

1. Conformally coat circuit boards. Mask where required.

2. Replace rear panel connectors with positive-locking types and secure wiring with tie-downs.

Materials Usage

1. Provide 150-hour off-gas bakeout

2.20.6 Cost Analysis

Modification

Basic Cost		$ 7,180
Modification Cost		
Fabrication	$ 3,611	
Engineering	6,100	
Test	2,944	
Documentation	2,160	
Program Management	741	
Total Modification Cost		$ 15,556
Total Cost		$ 22,736

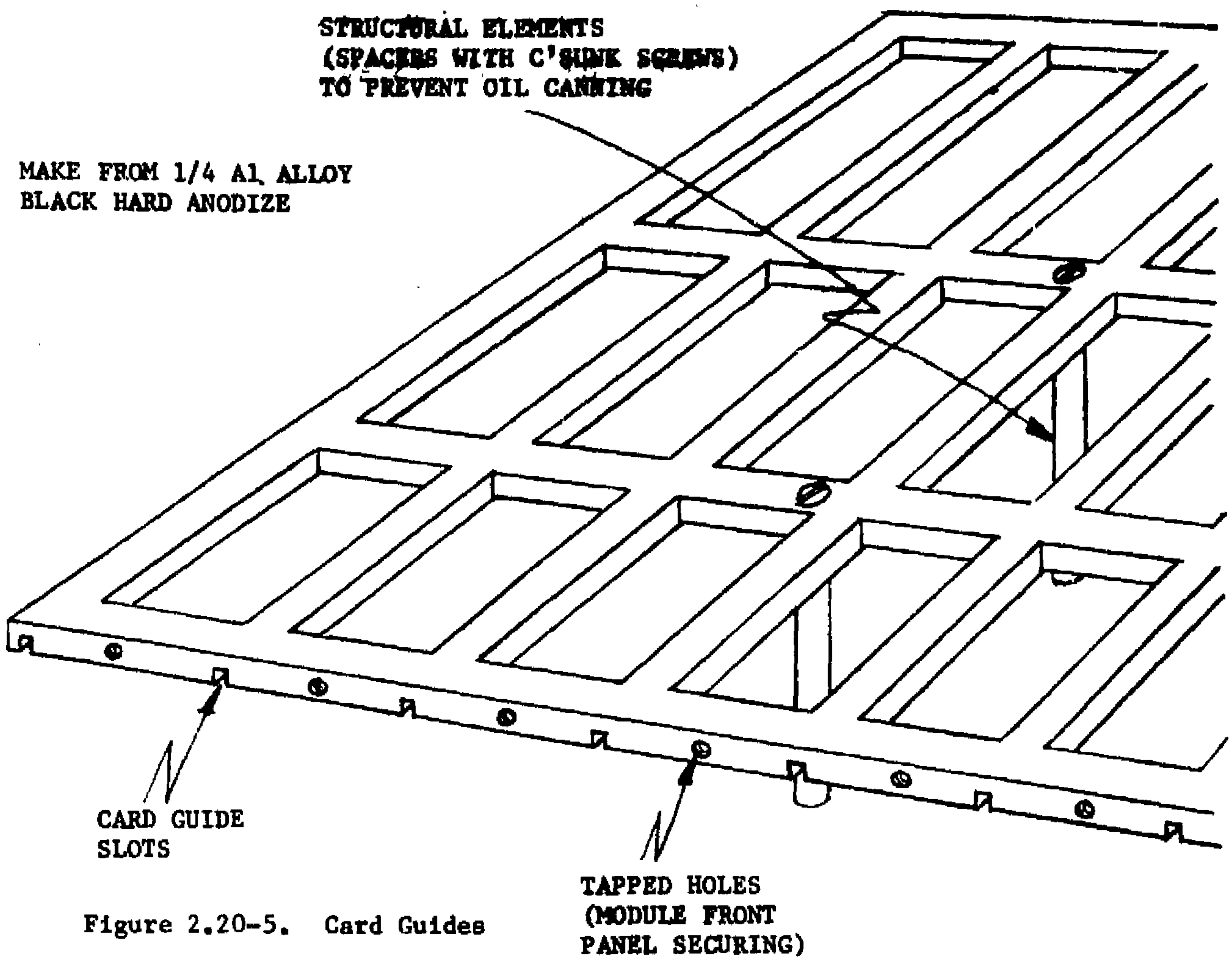

Figure 2.20-5. Card Guides

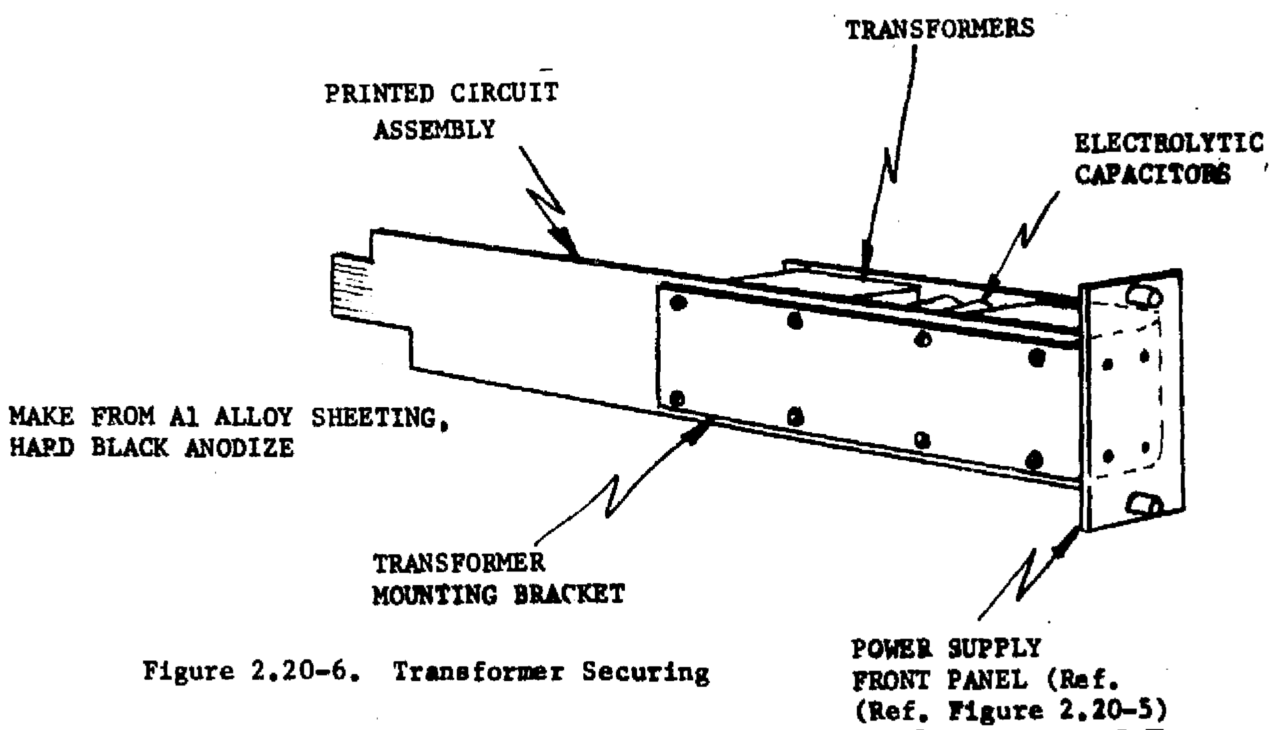

Figure 2.20-6. Transformer Securing

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. Model 126-021 ASSEMBLY NAME Amplifier - NEFF NEXT ASSY NO. ____ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	EXPD.	COST $ MAT'L	LABOR	TOTAL
		Remove PC Latching			1 25	15						
		Remove Nylon Guides	2		75							
		Fab. & Install Aluminum Guide	2	16 00	1 00	1 20		1 00		40 00		
		Alter Front Panels	16	1 50		45						
		Fab. Transformer Supports	2	2 00	1 00	20	50	1 00		3 00		
		Conformal Coat PCB's	17		21 25	3 43		4 00		51 00		
		Replace Panel Conn.	48		24 00	6 00		4 00		240 00		
		150 Hour Bake Out						16 00		500 00		
		Install tie downs	AR		1 00					2 50		
		Support of Above Items.						5 00	20 00			
		Retest & Calibrate				20 00	60 00					
		TOTAL HOURS		19 50	50 25	31 43	60 50	31 00		836 50		
		TOTAL								836 50	2774 50	3611 00

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		TOTAL
		TOTAL
		TOTAL

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2-255

SD 74-SA-0047-3

Space Division
Rockwell International

New Development

Cost	$ 51,000
Weight	16 pounds
Complexity	0.70
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter Avionics

2.20.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal range (-40 F to +167 F) capability
   a. Respecify 18 parts and replace 200 per rack assembly for vacuum and thermal range.
   b. Provide vacuum and thermal chambers and test time delta (from room ambient baseline) for qualification and acceptance.
2. Provide connector interface for external item testing to removable assembly level
   a. Add one 75-pin interface (rack) test connector
   b. Add 75-wire test harness - rack to amplifier and P/S cards
   c. Assume PCB input/output are adequate for isolation/ verifying amplifier/power supply operation - no PCB patch wiring
   d. Add hard mounted test signal isolation circuit board (30 discretes)
3. Seal the following test connectors/wiring junctions against moisture
   a. Two external interface rack connectors
   b. Seventeen PCB to internal rack connectors (printed PCB pins)
4. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**
5. Human factors modifications
   a. Add captive 1/4 turn panel mount fasteners (4)
   b. Add silkscreen operating instructions on panel (64 controls; 4 groups of 16)

2.20.8 Delta Modification Costs

Fabrication	$ 1,421
Engineering	22,724
Test	5,686
Documentation	2,562
Program Management	1,620

Total delta modification cost $ 34,013

2.20.9 Data Sources

1. Visual examination
2. NIC 359A/071 Specifications/Model 126. Neff Instrument Corporation
3. Operation and Maintenance Manual. Model 126 Wideband Differential Amplifiers
4. Neff Amplifier Sales Brochure
5. Telecon June 3, 1974 with Neff personnel

2.21 STRIP CHART RECORDER

Manufacturer: Honeywell Inc.

Model No.: 1858

Cost: $ 6074

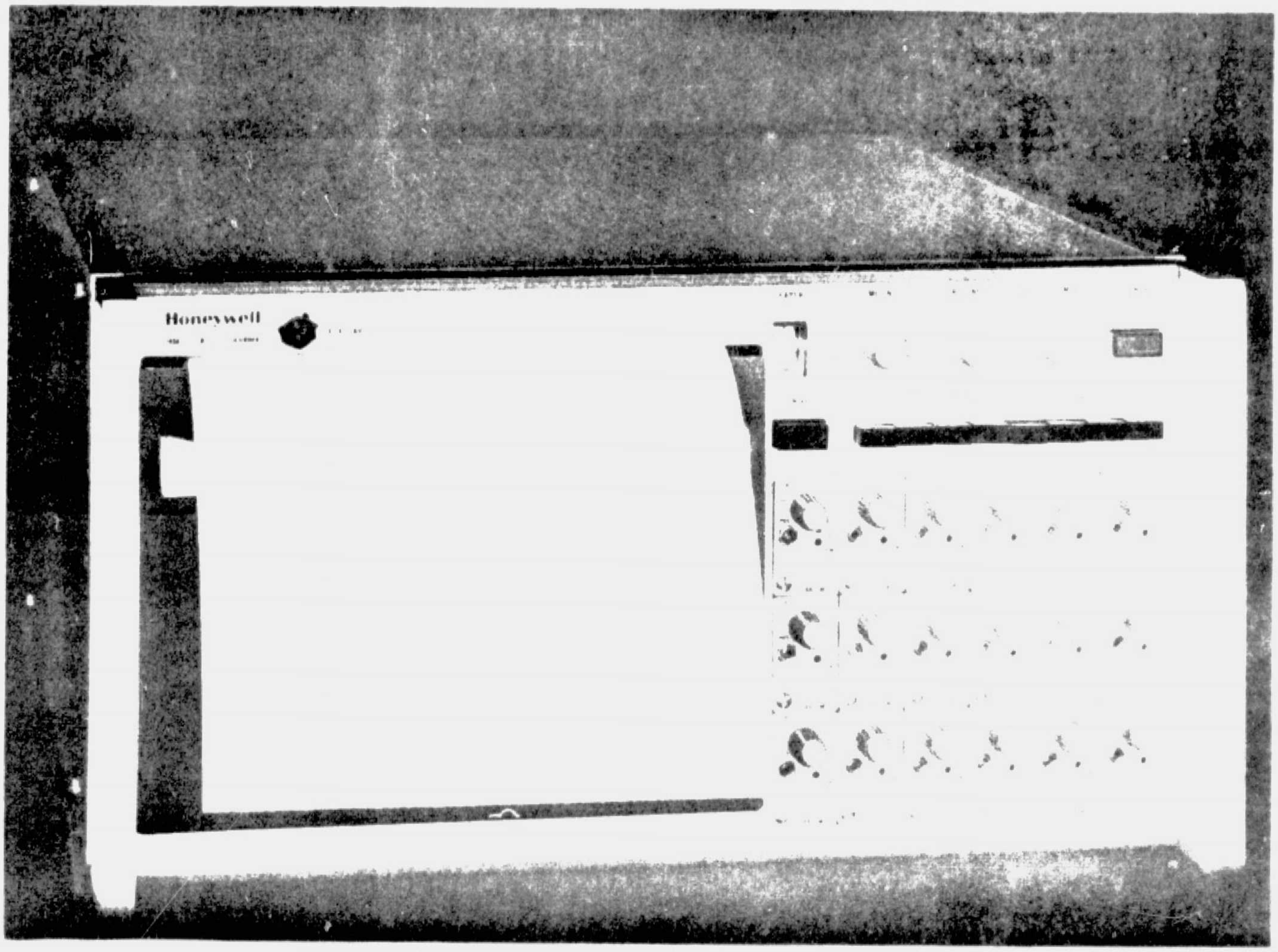

Figure 2.21-1. Honeywell Strip Chart Recorder - Model 1858

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2.21.1 Description

Records that are relatively insensitive to normal room light are produced without inks, powders, styli, electrostatic charges, liquid, electrical arcs or chemical vapors. Ultraviolet light is generated by a cathode-ray tube and directed through a special fiber-optic faceplate onto photosensitive paper.

Front panel openings accept up to 18 individual signal-conditioning modules. Various plug-in modules are available to cover a wide variety of applications. Among these are: high, low, and medium gain differential amplifiers, an impedance interface, a strain-gage control, and a thermocouple control. These signal conditioners allow recording within the dc to 5000 Hz range and accept input signals from 100μV to 300 V. Since the plug-in signal conditioning modules do not have to supply power to drive pens or galvanometers, they have been miniaturized and use state-of-the-art integrated circuits.

All plug-in modules contain an analog-voltage-to-time converter. The converter produces a pulse with a duration proportional to the amplitude of the input signal. These pulses unblank the CRT which is swept at a fixed rate of 50 kHz. To avoid a dotted trace presentation, as exhibited on other sampling or time-shared systems--such as multistyli recorders, a memory circuit connects the blanked samples to yield a continuous trace.

To assist in measuring the amplitude and time of recorded signals in calibrated increments, the Model 1858 places longitudinal amplitude reference lines and transverse time lines on the record.

A wide range (1200:1) dc servo system allows a selection of paper speeds from 0.1 to 120 ips in 42 discrete steps. A built-in takeup unit is offered as an option.

All operator controls are on the front panel. These include a power switch, speed selector pushbuttons, record drive switch, timing interval selector, grid line selector, and automatic record timer. Indicators are also provided for power on, drive on, and paper supply.

2.21.2 Performance Characteristics

General

Recording System. Single fiber-optic, cathode-ray tube in direct contact with direct-print photographic paper produces all data traces, timelines, gridlines, and trace identification recordings. Single 8-3/4-inch high cabinet houses paper supply, paper takeup, drive system, fiber-optic, cathode-ray tube, power supplies, and all associated electronics, as well as openings for signal conditioning modules for up to 18 data channels.

Recording Medium. Direct print photographic oscillograph recording paper, spec 2 (spooled emulsion side out on 1-1.8 inc I.D. core).

Record Width - 8 inches.

Record Capacity. 3-1/4-inch max. roll diameter; 100-ft standard base, 200 ft extra thin base.

Recording Channels. 18-max. single-width (1 inch) modules, 9 max. dual width (2-inch) modules, or combinations.

Operating Specifications (All specifications apply after 30-minute warmup)

Frequency Response. DC-5 kHz sinewave, 15 kHz squarewave; except as otherwise limited by singal conditioning module selected.

Input Data Sampling Rate. Approximately 50 kHz (sweep time 15μsec; fly-back time 5μsec).

Trace Dimensions. Max. 0.012-inch dynamic, 0.020-inch static (plus applicable signal conditioning noise spec).

Trace Amplitude. Max. 7.2-inch pk-pk or single deflection throughout dc-5 kHz frequency range.

Trace Positioning. Controls on signal conditioning modules permit electrical positioning of any channel at any point across the record.

Trace Off. Switch on signal-conditioning modules permits any channel to be turned off the record.

Gridlines

Spacing. Nominal 0.2 inch (5 mm) each fifth line (1 inch, 24 mm) accentuated.

Accuracy. Within ±0.5% full scale relative to data. Gridlines vary in spacing to compensate for nonlinearity of CRT.

Line Width. Minor lines, 0.010 inch, maximum; accentuated lines 0.020-inch maximum.

Record Drive System

Type. Wide range dc servo with 1200:1 speed range. No gear or clutches.

Speed Selection. Five front panel pushbutton speed selector switches of 1, 2, 4, 8, 16-inch/sec (25, 50, 100, 200, 400 mm/sec) plus three multiplier pushbutton switches of X.1, X1, X10 give 42 discrete speed steps. 1, 2, 4, 8 may be engaged in combination, producing binary additive speeds of:

X0.1 range:	0.1-1.6-inch/sec in 0.1 inch/sec steps
X1 range:	1-16-inch/sec in 1 inch/sec steps
X10 range:	10-120-inch/sec in 10-inch/sec steps

Remote Speed Control. By releasing front panel speed multipliers and providing an externally supplied voltage of +0.008 to +10.0V, speed may be varied from 0.1 through 120 inch/sec. Input impedance is 2000 $\pm$1% ohms. Polarity positive with respect to ground.

Acceleration Time. To 80-inch/sec <250 msec; to 120-inch/sec <500 msec.

Speed Markings. Front panel marked in inches per second. Adhesive overlay provided for converting to metric equivalents of 25, 50, 100, 200, 400 mm/sec.

Recording Periods (continuous). 200-ft roll: 6.6 hr at 0.1 inch/sec; 20 seconds at 120 inch/sec. 100-ft roll: 3.3 hrs at 0.1 inch/sec; 10 seconds at 120 inch/sec.

Accuracy. $\pm$5% with 1, 2, 4, 8, or 16 speed selector pushbuttons engaged; $\pm$7% with additive speed selected, over full voltage and environmental range. Typically $\pm$3% at nominal voltage and environment.

Auto Record Length Control. Front-panel control selects from 1 to 60 sec drive time. Automatic control can be manually overridden by releasing drive switch. The cycle will be restarted when drive switch is reactuated.

Record Takeup (option). Internal. Will takeup and spool full capacity of supply roll at all drive speeds, either on continuous or interrupted basis, over full environmental range. Records can be made with or without takeup as desired.

2.21.3 Physical Characteristics

Size

Rack Mounted - 8.75 h x 19.1 w x 21.0 d, inches (22.2 x 48.5 x 53.3 cm)

Weight

1858 - less signal conditioning modules or accessories, 65 lb (29.5 kg)

Signal conditioning modules - single width 5 oz; dual width 10 oz.

2.21.4 Suitability Analysis.

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. Figure 2.21-2 shows the construction of the model 1858. Y-shaped enclosure in top view contains CRT. Circuit board size and retention is shown in the lower figure. Chassis is cast aluminum.			
Signal conditioning modules are installed in front of unit (see Figure 2.21-1). Figure 2.21-3 shows typical signal conditioning module. IC component is indicated by pen.			
Unit can be obtained in rack mounted configuration.			
MATERIALS			
Metalized photosensitive paper Glass Aluminum Fish paper PVC wire insulation Phosphorus in CRT Fiberglass phenolic circuit boards Lubricant			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
<u>Vibration.</u> Operating: designed and tested to requirements of MIL-T-21200G, para. 3.2.19.4 (except 5-15 Hz, 0.06 inch pk-pk; 15-25 Hz, 0.04 inch pk-pk; 25-55 Hz, 0.0032 inch pk-pk); non-operating: designed and tested to meet requirements for transportation and packaged shipping.			X
<u>Shock</u>. Designed and tested to meet requirements for normal bench handling, transportation, and packaged shipping.	X		
Circuit boards require additional support.			X
Military type screw connectors in rear of unit (Figure 2.21-4).			
ELECTRICAL POWER			
107 - 127 v - 50 to 400 Hz 214 - 254 v - 50 to 400 Hz	X		

3. High Voltage Assembly
5. Video Amplifier
6. Trace Identifier (optional)
7. Clock
8. Gridline Generator
9. Timeline (optional)
10. +40 V and +5 V Power Supply
11. $\pm$12 V Power Supply
12. Servo

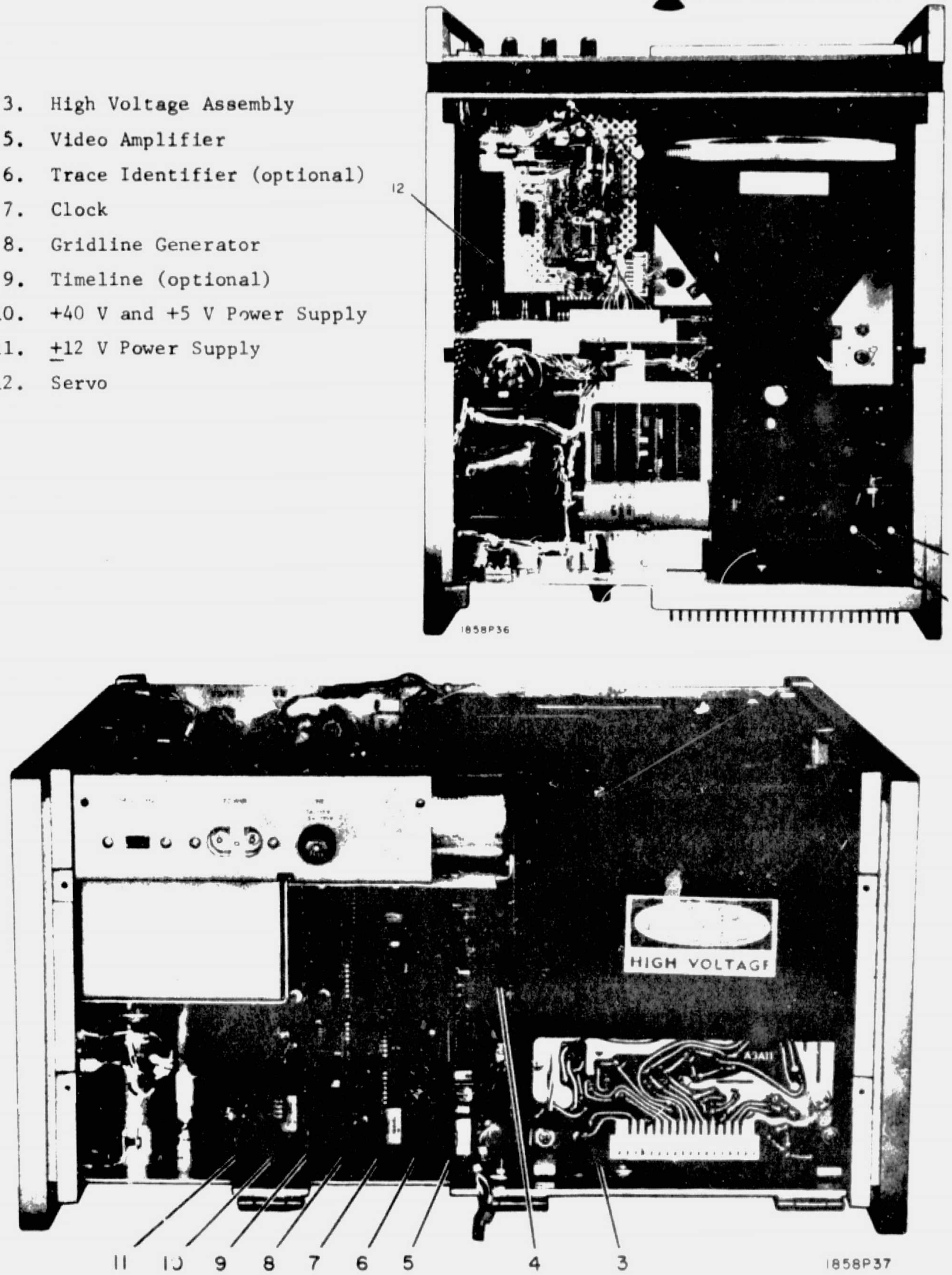

Figure 2.21-2. Top and Rear Views Of Model 1858

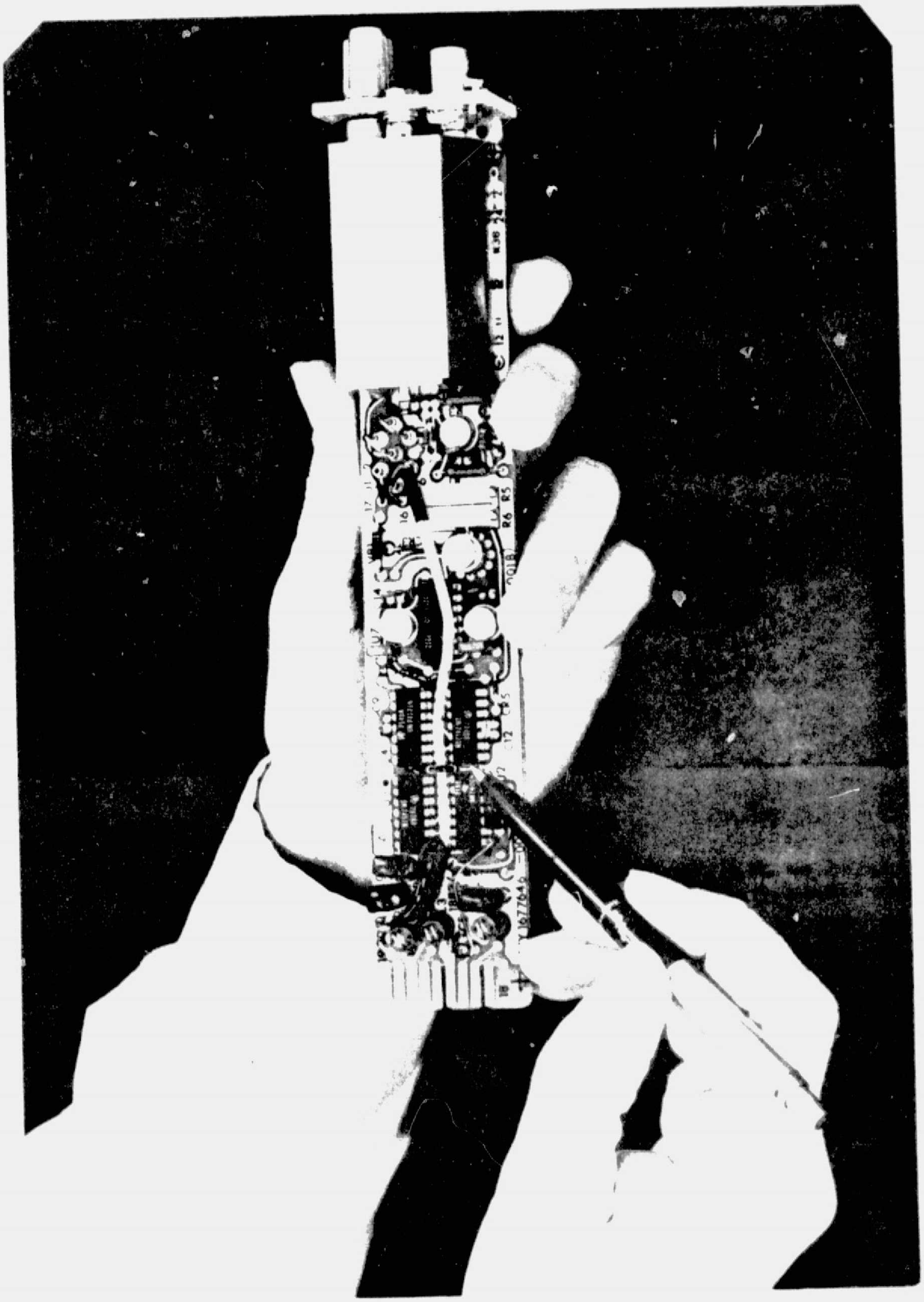

Figure 2.21-3. Signal Conditioning Module

Table of Typical Power Requirements* (120 V, 60 Hz Reference)

Paper Drive (inch/sec)	Spill-Out Mode (rms watts, no signal conditioning modules installed)	Take-Up Mode (rms watts, no signal conditioning modules installed)
Off	91	91
0.1	104	110
1.0	110	120
10.0	123	135
50.0	164	197
80.0	188	230
120.0	248	306

*Notes:

1. Peak currents typically 2-3 times the rms value, due to peak rectifiers used in system
2. Peak "power-on" surge current, first cycle, is appox. 14A; steady state reached in approx 180 msec
3. At line frequencies of 50 and 400 Hz, wattage approx. 5% greater than above figures

Signal Conditioning Modules

Type	Watts (rms)
1885	2.8

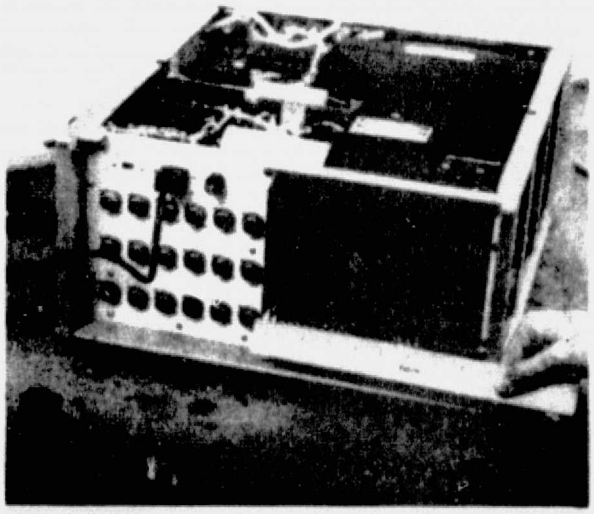

Figure 2.21-4. Rear Mounted Convector Plate

	Disposition: Accept	Disposition: Verify	Disposition: Unaccept
DATA MANAGEMENT COMPATIBILITY			
>5 volts I/O and control - digital and analog	X		
EMI SUSCEPTIBILITY AND RADIATION			
Has perforated thick metal case	X		
Isolated signal - chassis grounds	X		
>5 volt I/O voltages at low impedances	X		
NOISE GENERATION			
Chart noise at high speeds less than 40 db	X		
FLAMMABILITY			
PVC wire insulation			X
Typical electronic components			X
Has metalized paper in enclosed container. Flames do not propagate downward	X		
TOXICITY			
Motor and chain drive lubricants			X
Typical electronic components			X
Phosphorus in CRT		X	
CONTAMINATION GENERATION			
CRT shield has holes which could allow glass fragments to escape			X
RELIABILITY			
Basic unit - MTBF 2770 hrs using MIL-HDBK 217A failure rates	X		
Tube life (typical) - CRT gun, 5000 hrs (power on); phosphor, 2500 hrs (drive switch on)			

	Disposition		
	Accept	Verify	Unaccept
ATMOSPHERE			
Humidity - Operating: 5-95% relative, non-condensing (except as otherwise stated in signal conditioning module specifications); non-operating: 5-95% relative, non-condensing.	X		
Altitude - Operating: to 10,000 ft; non-operating: to 50,000 ft.			
AMBIENT TEMPERATURE			
Operating: 0 to +50°C; non-operating: -55 to +60°C; rate of change: 10°C/minute max.			
EQUIPMENT COOLING			
Rear mounted natural convection finned plate. Air flow in rack will provide adequate circulation.	X		
ZERO-G EFFECTS			
Direct transfer of CRT image on photo-sensitive paper eliminates gravity and vibration sensitive galvanometer type ink pen used on most strip chart recorders.	X		
OPERABILITY			
Handles are not 0.8 inch radius.			X
Knobs protrude			X

2.21.5 Modifications

Construction

Shatterables. Screen CRT openings.

9-G Mounting/Integrity - none

Protrusions and Edges Safety. Rack-mounted recorder will require protection rails similar to Figure 7 of Design Guidelines.

Shock-Vibration-Acceleration-Acoustics Resistance. Provide card supports per Figure 2.21-5. Retain all wire cables with cable clamps and all bulkhead grommets will be replaced with nylon grommets. Conformal coat approximately 15 printed circuit boards. Pin knobs to shafts.

Materials Usage

Concentrations of Flammable/Unidentified Materials. All wire will be changed to TFE; all fasteners will be changed to CRES; replace cork gasket securing CRT with silicone rubber. Provide TFE fabric gasket and metal door on paper compartment per Figure 2.21-6.

Non-Prevelant Commercial Materials (or Warnings on Handling/Usage of Item. Chart paper, insulation material.

Bakeout for 150 hours to expel volatiles.

Replace 20 knobs with polyimide; pin to shafts.

Thermal Compatibility

Add forced air modification per Figure 2.21-6.

Zero-G Compatibility

Instrument would be purchased with internal record takeup option.

Fabricate fan mount and air exit box per Figure 2.21-6.

2.21.6 Cost Analysis

Modification

Basic Cost		$ 6,975
Modification Cost		
Fabrication	$ 6,882	
Engineering	11,297	
Test	4,416	
Documentation	2,160	
Program management	995	
Total Modification Cost		$ 25,750
Total Cost		$ 32,725

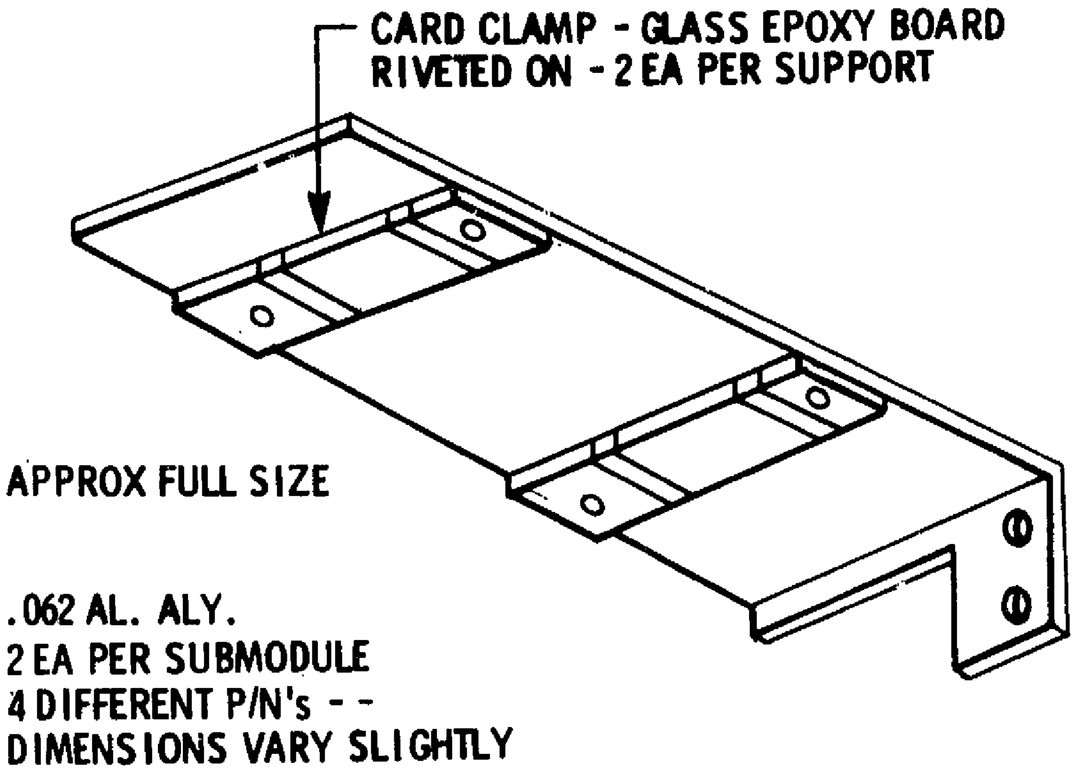

Figure 2.21-5. Submodule Card Support

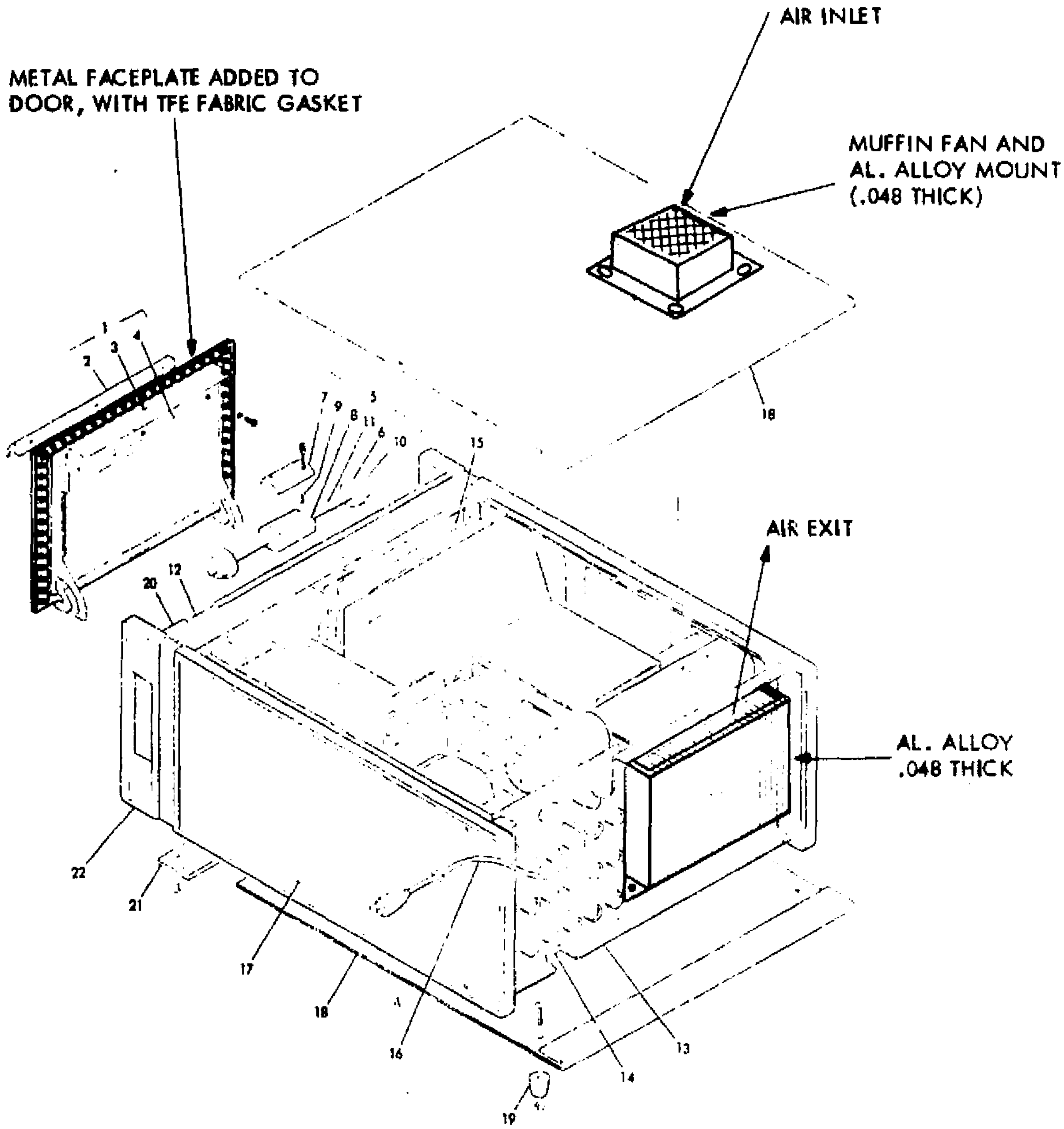

Figure 2.21-6. Material Replacement and Forced Convection Modifications

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. Model 1858 ASSEMBLY NAME Oscillographic Recorder NEXT ASSY NO. Honeywell DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD.	COST $: MAT'L	LABOR	TOTAL
		Install Nylon Cable Clamps	25	2 50	2 50	1 00					6 70		
		Replace Bullhead Grommets	10		1 00	20					3 00		
		Upgrade PCB's to A/B Rating	15		18 75	3 00					45 00		
		Fab. Protection Rails	2	2 00		20					10 00		
		Over Spray Coating				75					45 00		
		Rewire w/TFE	75		7 50	3 25		20 00	20 00		10 00		
		Replace Fasteners w/SS NYLOC	200		30 00	20 00		40 00	40 00		50 00		
		Replace & Fab. CRT Gasket	1						1 00		5 00		
		150 Hour Bake						16 00			500 00		
		Pin Knobs to Shafts (Remove Switches)	21	2 10	1 50	1 00			4 00		2 80		
		Fab. & Install Screens to CRT		2 50		1 00			3 00		7 50		
		Fab. Card Support	8	12 00		1 00			2 00		28 00		
		Fab. Retainer	2	1 25		25			50		2 50		
		Rab. Mount & Air Exit Box		8 00		1 00			3 00		65 00		
		Fab. Knobs Vespel	21	21 00		2 10					525 00		
		Other System support				6 50		16 00	10 00	20 00			
		Test & Calibeate				16 00	32 00						
		TOTAL HOURS		52 85	61 25	57 50	32 00	92 00	85 50	20 00	1311 00		

LOT SIZE FROM	LOT SIZE TO											
		RATE										
		O.H.										
		TOTAL								1311 00	5570 99	6882 29
		TOTAL										
		TOTAL										

Beckman INSTRUMENTS, INC.

SHEET 1 OF 1 BY STATA

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2-272

SD 74-SA-0047-3

Space Division
Rockwell International

New Development

Cost	$ 363,000
Weight	25 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Space Station Displays and controls

2.21.7 ECO06M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal delta capability

   a. Respecify and replace 100 electronics parts

   b. Add vacuum (only) chamber and test time for qual and acceptance

   c. Replace lubricant in one servo motor, 1 tack generater, and paper roller bearings (2 or 3 rollers)

2. Provide connector interface to test item to replaceable assembly

   a. Add three 50-pin external panel connectors

   b. Add a 150-wire test harness to 45 assembly connectors

   c. Add a hardmounted test signal isolation PCB (60 discretes)

   d. Patch wire 27 assemblies/PCB's test signals (3 each) to spare connector pins.

3. Seal the following connectors/wire junctions from moisture

   a. 36 PCB (MS type) connectors (have printed pins on PCB's)

   b. 3 internal harness connectors

   c. 18 panel I/O connectors (sheel type)

   d. 18 panel BNC coax connectors

4. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

5. Replace PVC as follows (delta to SEEIR mods only)

   a. 50 loose wires

6. Human factors mods as follows

   a. Add captive 1/4 turn panel mount fasteners (4)

   b. Add Op. Inst. on panel (31 controls)

2.21.8 Delta Modification Cost

Fabrication	$ 2,191
Engineering	33,359
Test	5,823
Documentation	2,562
Program Management	2,197

Total delta modification cost $ 46,142

2.21.9 Data Sources

1. Visual examination

2. Technical Manual 16778113-001L, Maintenance Instructions for CRT Visicorder Model 1858. Honeywell, November 1973

3. Technical Manual 16776882-001A, Instruction for High Gain Differential Amplifier Module - Model 1881-H6D. Honeywell. November 1972

4. Technical Manual 16778145-001C, Instructions for Strain Gage Control Unit - Model 1885-SGC. Honeywell. August 1973

5. Technical Manual 16776695-001, Instructions for Medium Performance Differential Amplifier-Module - Model 1883. Honeywell, November 1973

6. Technical Manual 16778289-001A, Instructions for Thermocouple Control and Microvolt Amplifier Assembly - Model 1886-TCU. Honeywell, August 1973

2.22 SPECTROPHOTOMETER

Manufacturer: Beckman Instruments

Model No.: 24

Cost: $ 2760

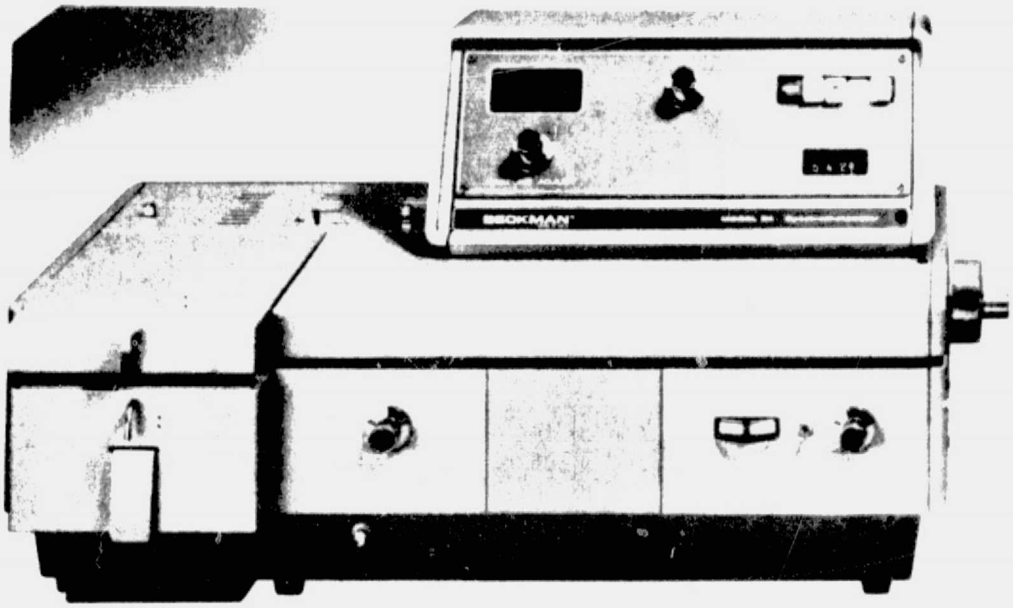


Figure 2.22-1. Beckman Spectrophotometer

2.22.1 Description

The scanning system consists of a Model 24 or 25 UV-Visible Spectrophotometer featuring double-beam optics, push-button controls, digital readout of Absorbance and Concentration, and computer compatibility. The scanning Model 24 and 25 also come with a stepper drive recorder for simplified running of spectra.

The system has a tungsten source, manual wavelength drive and fixed slits. The wavelength range on this instrument is 700 nm to 340 nm. The upper wavelength limit is a function of the phototube and the lower wavelength limit is a function of the source. The slit is fixed at 2 nm bandwidth. The system uses a DBG monochrometer which utilizes a filter-grating optical system. The grating has 1200 lines per mm and is blazed at 250 nm. The system may be operated in SB or DB and it utilizes a vibrating bridge assembly.

2.22.2 Performance Characteristics

Wavelength range	190 to 1000
Operating range	340 to 700
Presentation	Digital counter, 0.2 nm increments
Accuracy	±0.5 nm
Repeatability	±0.2 nm
Photometric range	
(a) Digital	0-2.000 Abs 0-8000 Concentration
(b) Recorder	0-0.1, 0-0.25, 0-0.5, 0-1.0, 0-2.0 Abs -0.3 to +0.7 Abs Concentration Zero Suppression to 2.0 Abs
Accuracy	±0.5% of value or 0.001 Abs, whichever is greater
Repeatability	±0.25% of value or 0.001 Abs, whichever is greater
Slits	Fixed at 0.8 mm wide by 1.5 mm high
Resolution	Better than 4 nm throughout
Baseline flatness	±0.009A throughout
Baseline stability	0.0004 Abs/hr
Stray radiation	<0.1% at 370 nm

2.22.3 Physical Characteristics

Size	24" l x 16" d x 14" h (61 x 40.6 x 35.6 cm)
Weight	70 pounds (31.8 kg)

2.22.4 Suitability Analysis

Disposition		
Accept	Verify	Unaccept

CONSTRUCTION. Unit is built on a cast aluminum chassis. A light source controlled by a grating mirror and lenses (Figure 2.22-2) shines into a liquid sample container. A cam/follower mechanism at the bottom of the unit controls the angle of the grating mirror (Figure 2.22-3). Electronics are mounted beside the light source and light path control box (Figure 2.22-4). This figure also shows large heat convector fins at the rear of the unit. The unit is bench mounted.

MATERIALS -

	UL Temp. Index
Nylon	
Type 101	75°C/115
FM - 10001	
Glass filled #6	65 UL SE
Black	
Natural	
Polyurethane foam	
Black	50°C Res to HP 190°F
Charcoal and adhesive used	
Gray	
Epoxy	
Plexiglas #2423 Red	(SE1, 2 SB) 130°F UL 140°F
Vinyl	50/85 UL
Neoprene	
Nylatron	
Resin-furane 7C-40	
Fishpaper	
Mylar type	
Paperboard	
ABS molding black	
Cycalac	
Lamac #5 or equivalent	
Rubber base cork	
Mercury gas in nixie tubes	
Chloroprene rubber sheet	
Cellulose acetate butyrate	
Polyethelyne	220/200
Kel-F	350/390
Felt	
Corrugated fiberboard #1100	

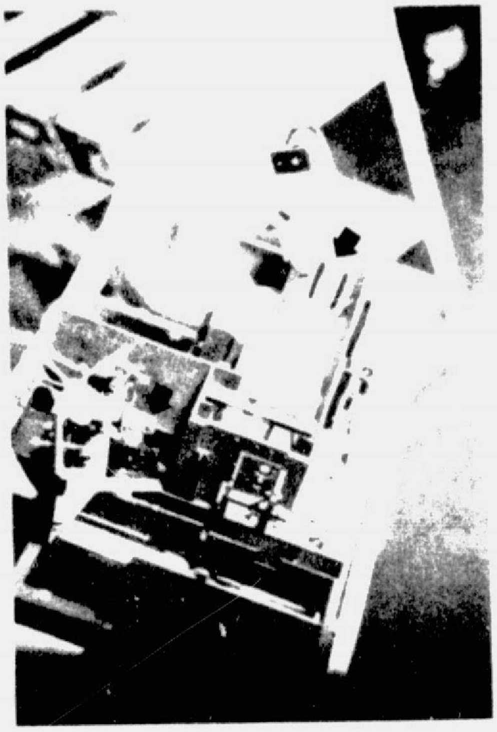


Figure 2.22-2. Light Source and Grating Mirror

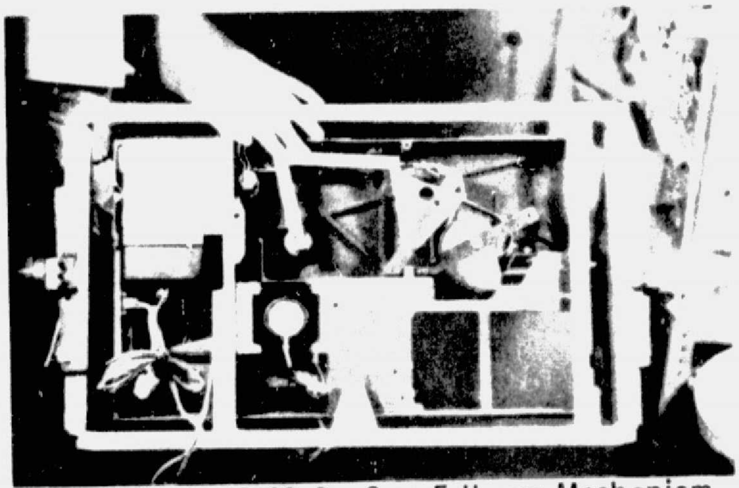


Figure 2.22-3. Cam Follower Mechanism

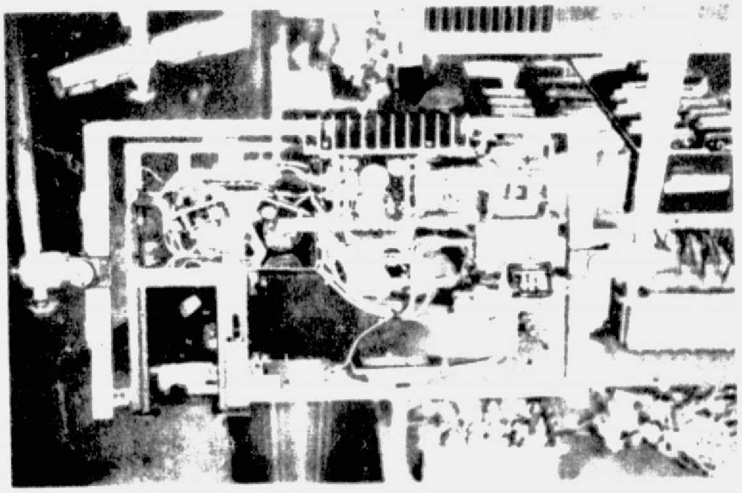


Figure 2.22-4. Electronics Installation and Convector Fins

SHOCK, VIBRATION, ACCELERATION AND ACOUSTIC ENVIRONMENT	Accept	Verify	Unaccept
Lamp housing held in place by large thumb screws which could work loose in vibration			X
Chopper requires immobilization during boost			X
Cam follower requires positive retention during boost to prevent chatter			X
End mounted motors			X
Transformer, circuit boards, capacitors not adequately mounted for vibration environment (see Figure 2.22-5)			X
Screws and bolt not positively retained			X
Nixie tubes - bottom supported			X
Sample door not positively retained			X

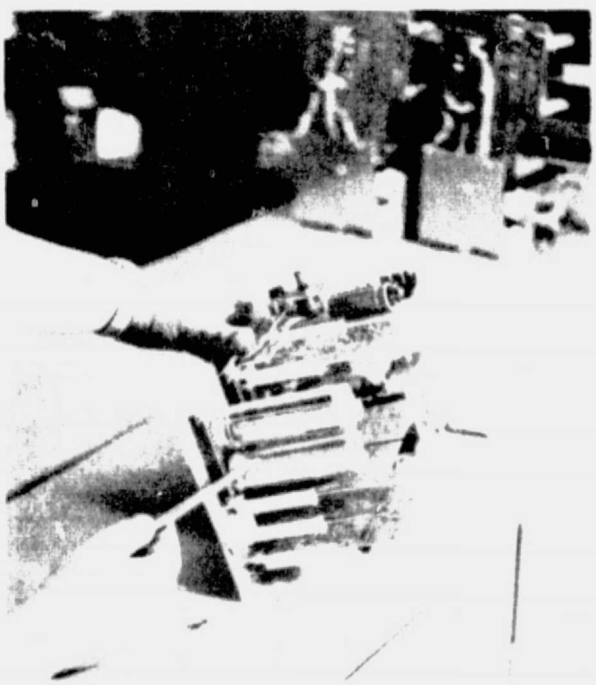


Figure 2.22-5. Electronics Component Mounting

	Disposition		
	Accept	Verify	Unaccept
ELECTRICAL POWER			
115 VAC ± 15V, 50/60 Hz 230 VAC ± 30V, 50/60 Hz	X		
DATA MANAGEMENT COMPATIBILITY			
System capable of driving external potentiometric recorder	X		
EMI SUSCEPTIBILITY AND RADIATION			
Radiation appears acceptable		X	
Sensitive to EMI from brush type motor. However such EMI generator not expected in Spacelab.		X	
Signal appears isolated from chassis		X	
NOISE GENERATION			
Fans could generate excessive noise		X	
FLAMMABILITY			
PVC insulated wire harnesses			X
Nylon			X
Resin-furane			X
Cycalac			X
Cellulose acetate butyrate			X
TOXICITY			
Polyurethane foam			X
Neoprene			X
ABS			X
Mercury gas in nixie tubes			X
Polyethelyne			X
Chloroprene rubber			X

	Disposition		
	Accept	Verify	Unaccept
CONTAMINATION GENERATION			
Glass - light source bulbs in case of breakage			X
- Nixie tubes in case of breakage			X
CONTAMINATION SUSCEPTIBILITY			
Grating mirror in sealed compartment	X		
ATMOSPHERE			
Compatible with Spacelab environment	X		
AMBIENT TEMPERATURES			
Compatible with Spacelab temperatures	X		
EQUIPMENT COOLING			
Rear mounted heat sink fins rely on natural convection			X
ZERO-G EFFECTS			
Samples container held in housing by gravity (Figure 2.22-6)			X
OPERABILITY			
Require 0.5" radii edge guards			X

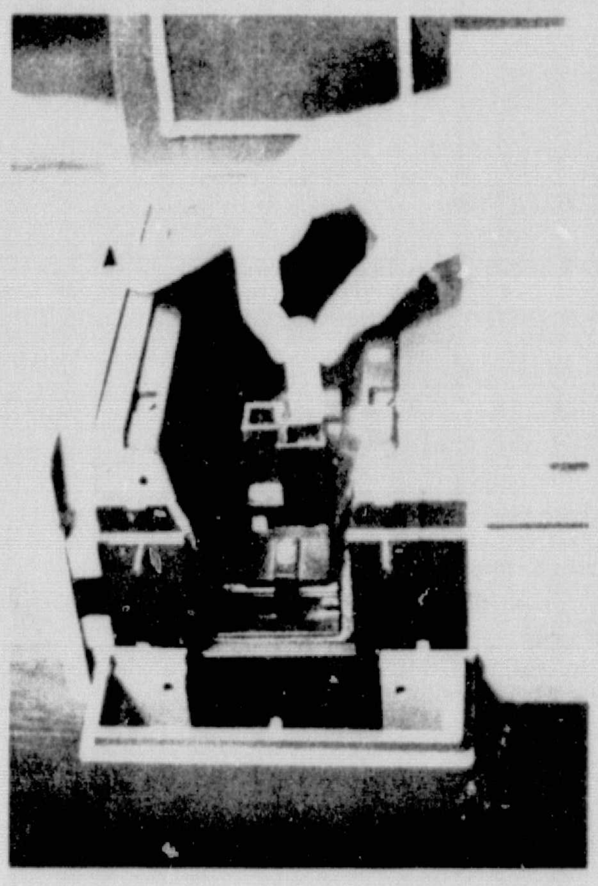


Figure 2.22-6. G Dependent Sample Container Housing

2.22.5 Modifications

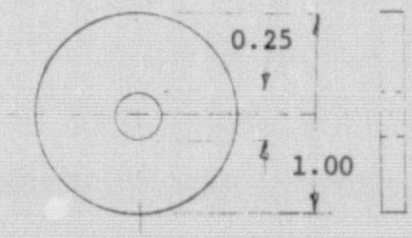
Construction

Shatterables. Shatterables are light sources, optical elements, sample and reference cells, and nixie tubes. It is not practical to changes these to non-shatterable components, so any fragments that might be generated must be contained.

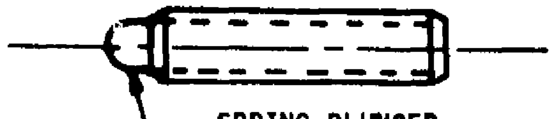
1. Cover slots in sheet metal (two places) with fine stainless screen.

2. Install silicone sponge rubber gasket around knob holes:

Assume six of these will be necessary. Fix in place with adhesive.



3. Provide positive latch for sample door so it won't fly open. Use a standard bullet/non-detent (Vlier, etc.)



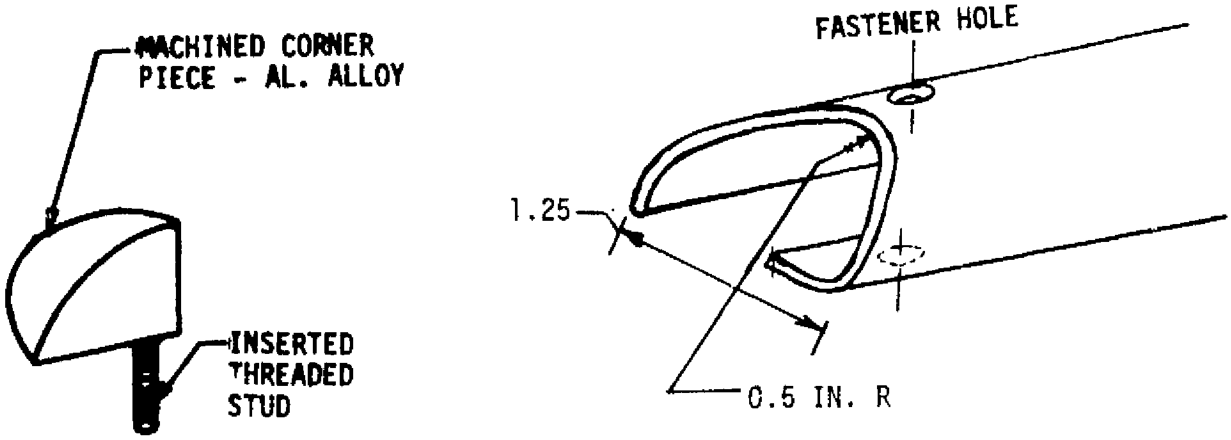
4. Silicone sponge rubber gasket to seal pushbuttons. Similar to Item 2.

5. For improved retention of fragments, put Lexan cover, 0.125 in. thick, over panel area.

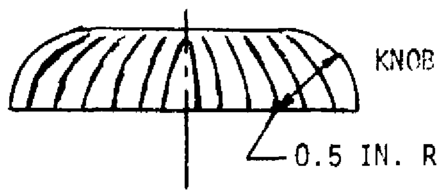
<u>9-G Mounting/Integrity</u>. Replace the sheet-metal cover on bottom of instrument with an aluminum alloy plate 0.25-inch thick, having hold-down provisions and mounting holes. See Figure 2.22-7.

<u>Protrusions and Edges</u>.

1. Dress edges with molding made from aluminum alloy. Extrusion:



2. Replace knobs with a more rounded design.



<u>19-Inch Rack Mount Capability</u>. Not strictly applicable. If put in a 19-inch rack, this instrument will be on a shelf enclosed in the rack.

Vibration

1. <u>Slit Arm</u>. Operation of this is gravity dependent. A fairly strong spring is needed to hold it against its stop. See Figure 2.22-8.

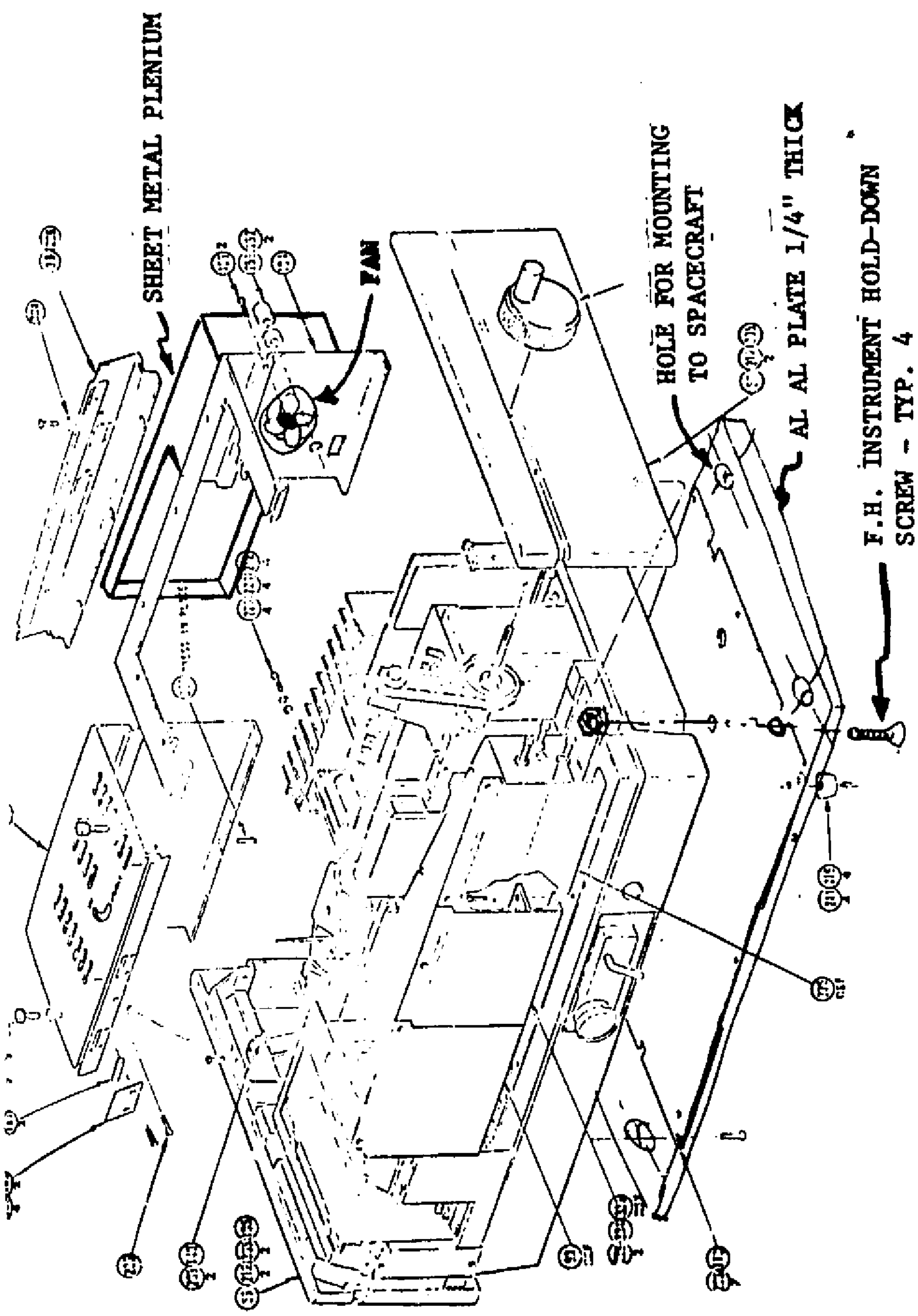


Figure 2.22-7. Base and Plenium Chamber Modifications

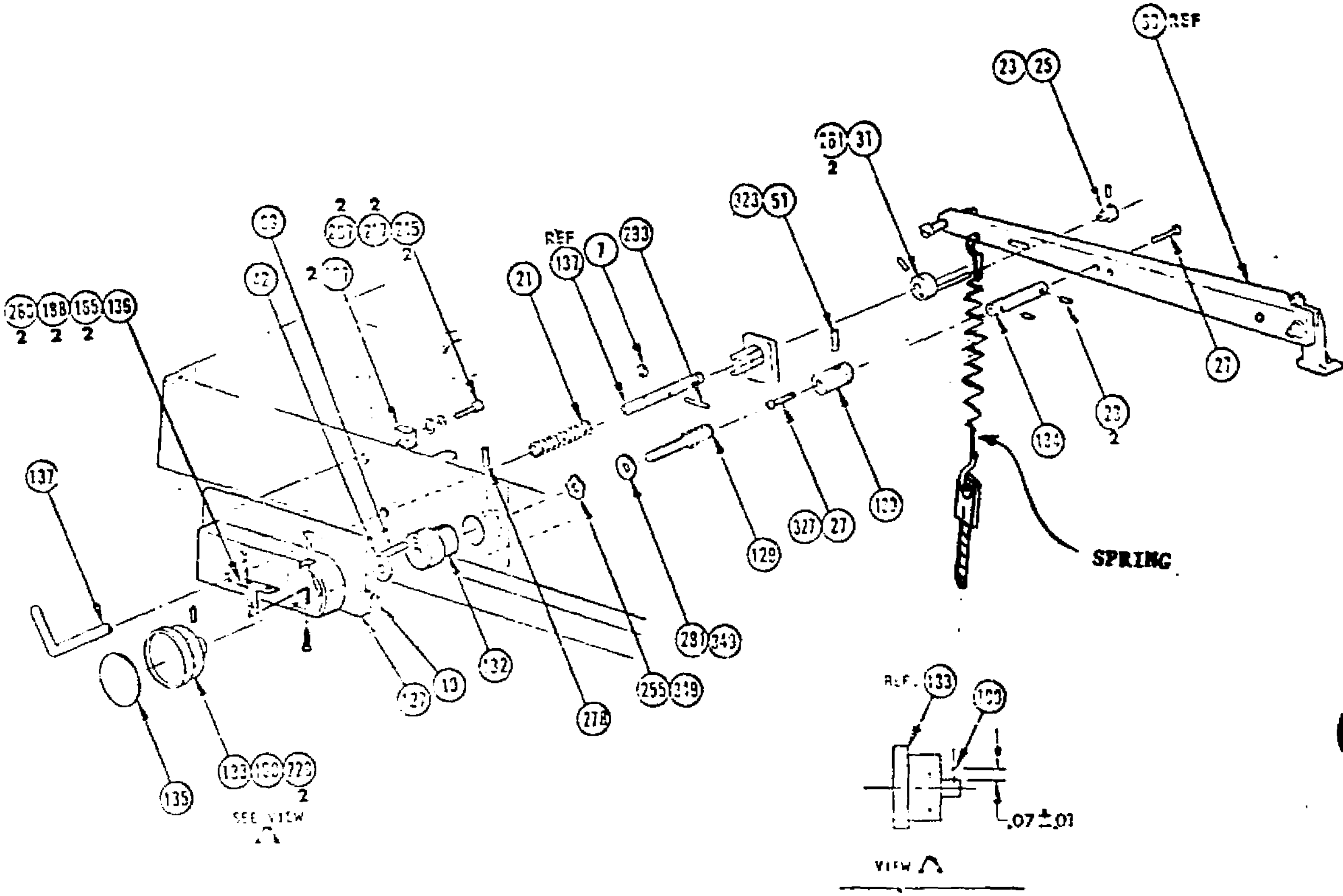


Figure 2.22-8. Slit Arm Hold-Down Spring

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2. Cam. Chattering of the spring-loaded cam follower against the cam would be a problem in vibration. Follower should be lifted off the cam and immobilized during launch/descent. Pulling on one of the links will do this. A pivoted, threaded block attached to one of the arms will be drawn back and held steady by means of a threaded rod. See Figure 2.22-9.

3. Chopper. This is a spring-suspended mass; needs to be immobilized during ascent/descent. A forked bar engages one of the rods of the chopper carriage under vibration. A hole must be cut in the instrument case for the bar to enter; and two tapped holes for securing it. Bar is aluminum alloy approximately 4 inches long. See Figure 2.22-10.

4. Light Sources. The deuterium source is well clamped and appears satisfactory. The security of the incandescent lamp in its socket needs to be improved. It is a flanged bulb with three keyhold sockets which fit over the pins. Replace These pins with studs and nuts. See Figure 2.22-11.

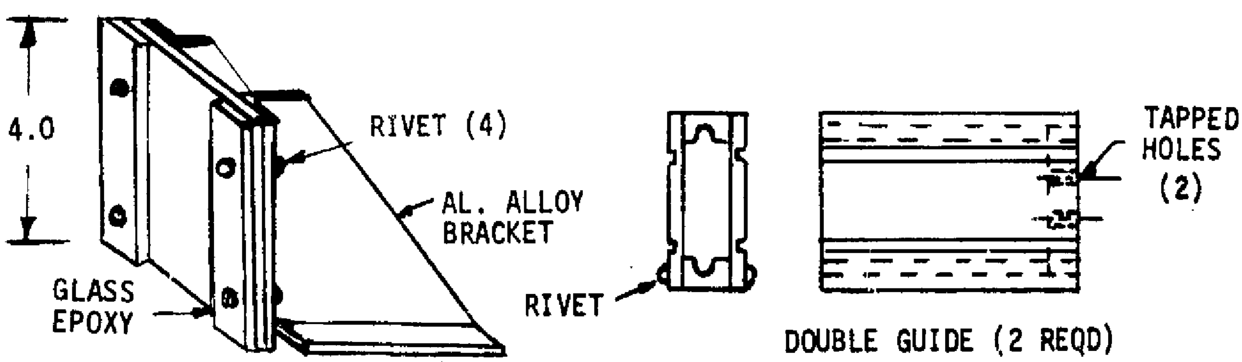
   The little relay mirror which switches the unit from visible to UV modes is not secure. Fix this by making the actuating arm clampable at the instrument cover. Parts are CRES (see Figure 2.22-11).

5. Motor. There are two cantilever-mounted motors. Lateral support is required. Fabricate sheet metal (0.062 CRES) bracket. See Figure 2.22-12.

6. Relay Mirror. To prevent six spring-loaded mirrors from bouncing on their seats, install the little clamps shown in Figure 2.22-12. Material is Vespel polymide--three per mirror.

7. Eleccronics. Improve support for circuit cards and large electrolytic capacitors.

   a. Make new card edge guides using glass-epoxy and 0.047 aluminum alloy.



SINGLE GUIDE (6 REQD)

DOUBLE GUIDE (2 REQD)

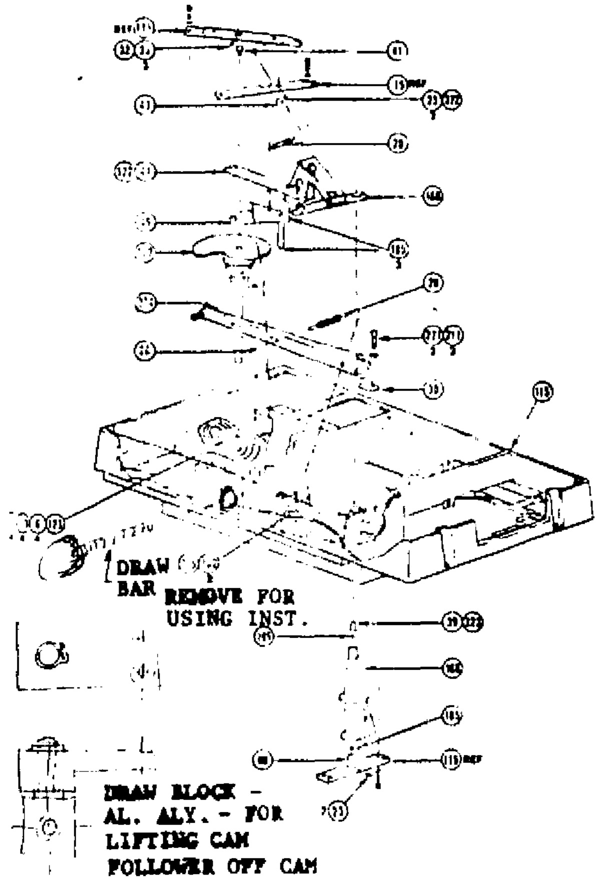


Figure 2.22-9. Cam Immobilization

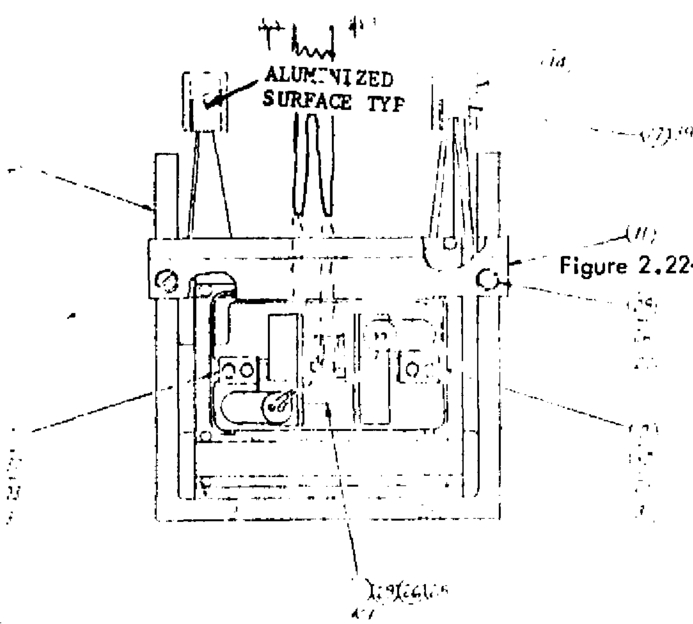


Figure 2.22-10. Immobilization of Chopper Forked Bar

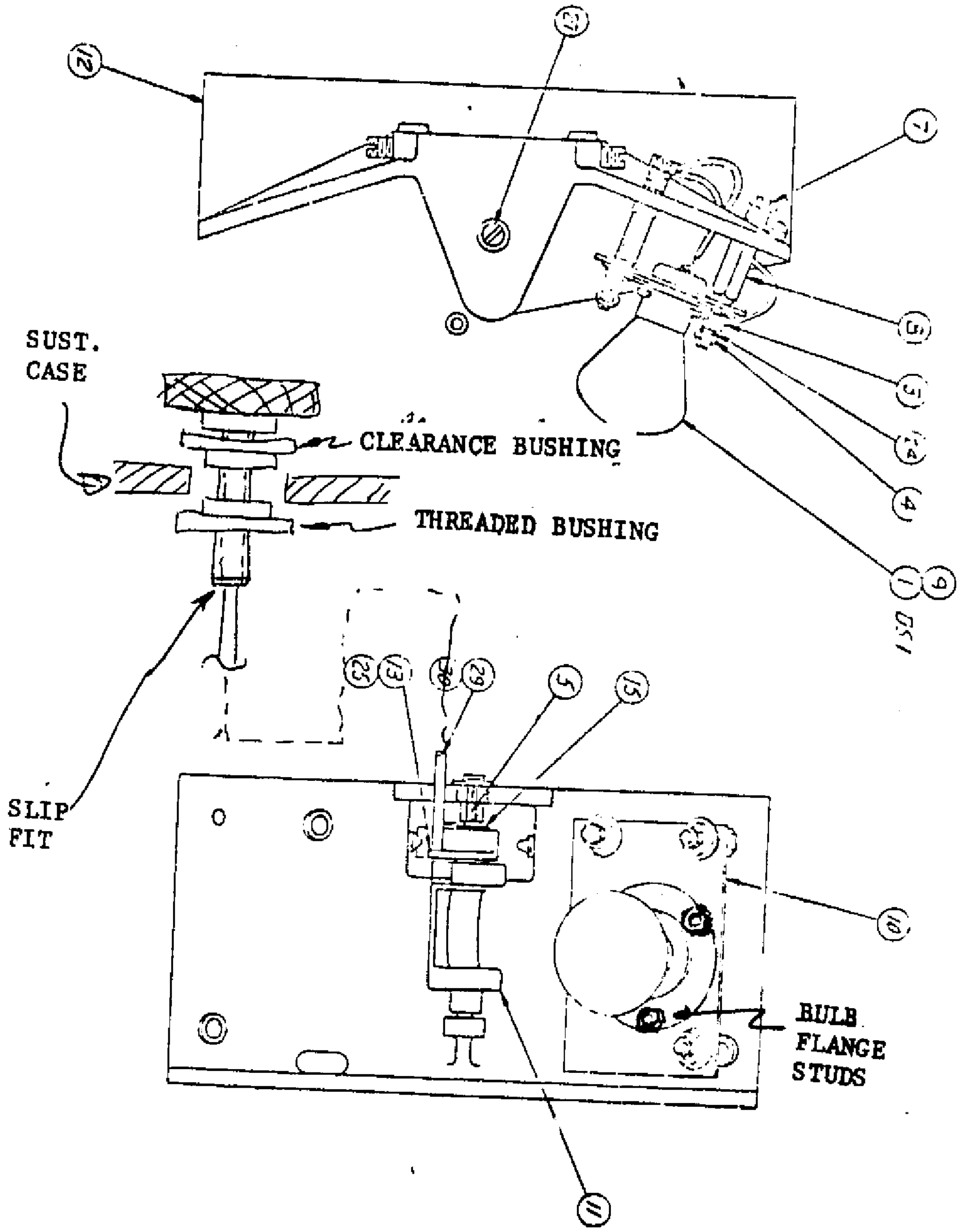


Figure 2.22-11. Light Source Securement

C-4

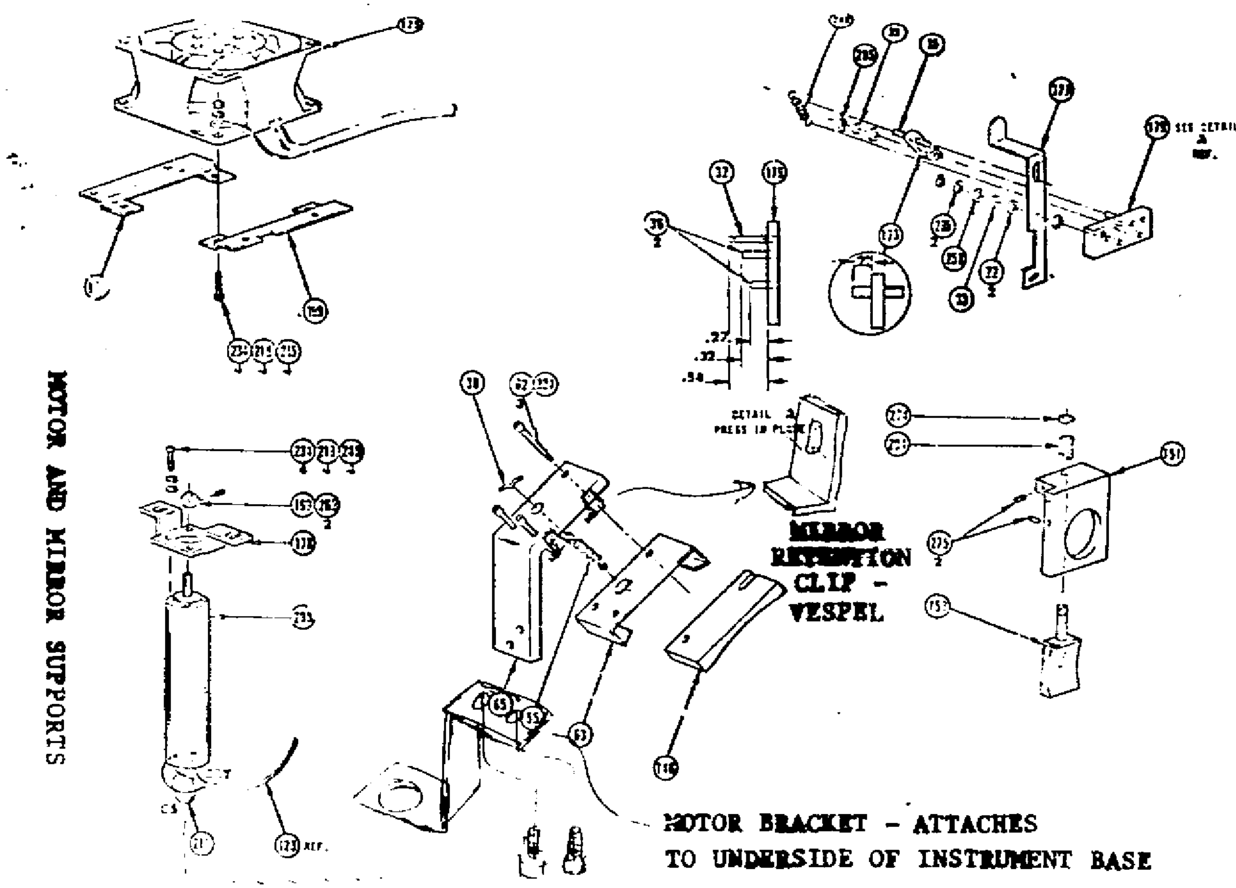
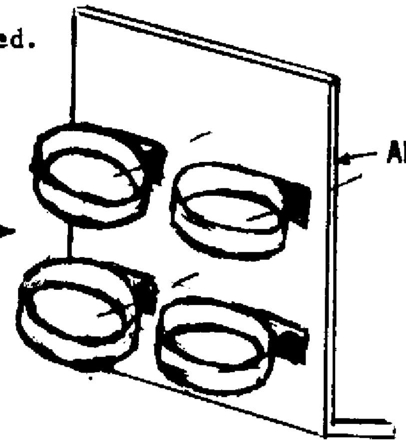


Figure 2.22-12. Motor and Mirror Supports

b. Capacitor Support. One required.



8. Nixie Tubes. Need support to steady them against vibration and assure that they stay in their sockets. Fabricate sheet metal bracket with silicone sponge rubber pad to cushion nixies.

9. EMI Susceptibility Protection. Add line filter to ac power lines.

10. Replace fasteners with Nylok (estimate 300 fasteners).

11. Fabricate transformer support brackets per Figure 2.22-13.

12. Fabricate numerical readout support bracket.

13. Pin 7 knobs to their shafts for proofing.

Material Usage

1. Flaking and Peeling Resistance. Remove pressure-sensitive "stick-on" color stripe tape.

2. Concentrations of Flammable/Unidentified Materials. Replace plastic pushbuttons (5) on panel with polyimide buttons. Remove plated plastic knobs and replace with polyimide. Apply conformal coating to transformer.

3. Non-Prevelant Commercial Materials. Numerous cadmium-plated steel parts; disassemble, strip and refinish with nickel plate. Rewire instrument with TFE wire.

4. Resistance to Combustion/Ignition. Satisfactory

5. Replace foam on lid with acceptable material.

6. Bake out for 150 hours to expel volatiles.

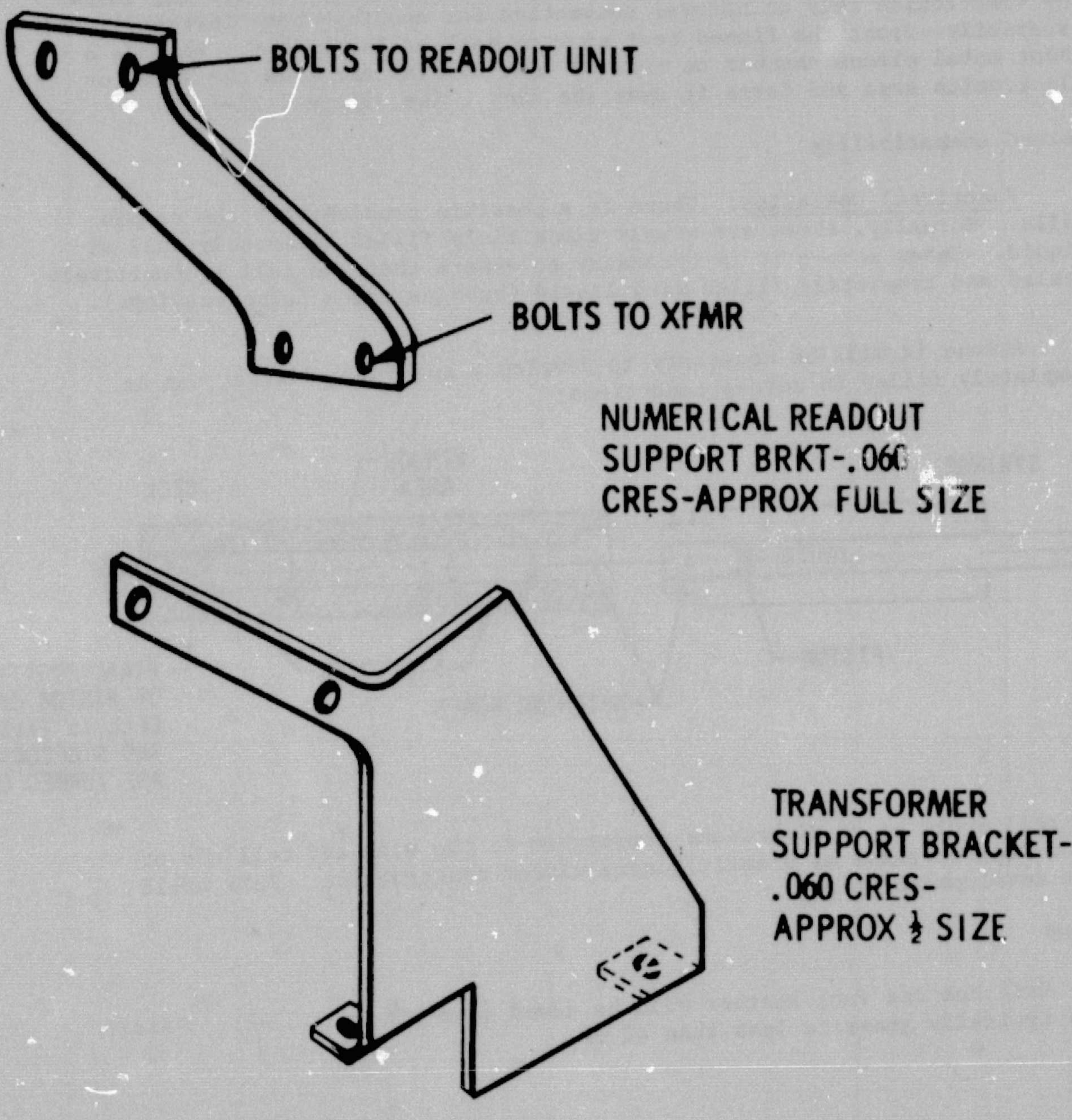


Figure 2.22-13. Numerical Readout and Transformer Support Brackets

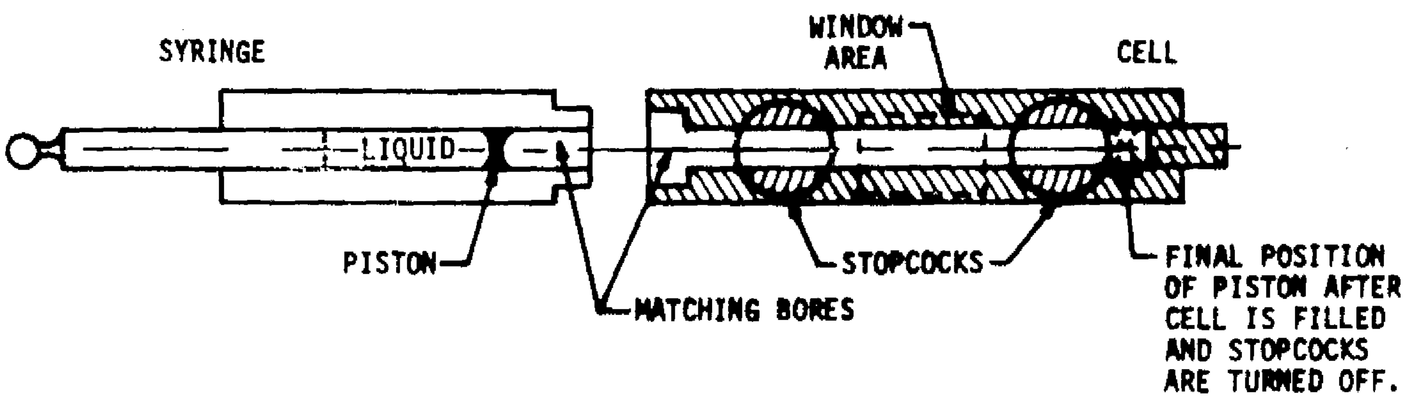
Thermal Compatibility

There is a blower in the unit, but it is primarily for cooling lamps. The electronics rely on natural convection for cooling--both internally and externally--front the finned heat sink on back of instrument. Provide a sheet metal plenum chamber on rear of unit to draw air from the interior electronics area and force it over the fins. See Figure 2.22-7.

Zero-G Compatibility

Functional Operation. There is a possible problem with the sample cells. Normally, these are simply glass vials filled reasonably full of liquid. Under zero-g it is necessary to ensure that the cell is positively sealed and completely filled with liquid (bubbles cause false readings).

Assume it will be necessary to develop a special cell that can be completely filled in zero-g conditions:



The cell would be of dimensions comparable to the standard cell and of either quartz/glass or plastic/quartz window construction. This would be a development item.

Noise

Unit has one fan; another will be added (see Figure 2.22-7). Axial fans typically generate less than 40 dB.

2.22.6 Cost Analysis

Modification

Basic Cost		$ 3,134
Modification Cost		
Fabrication	$17,135	
Engineering	17,885	
Test	8,832	
Documentation	2,160	
Program Management	2.239	
Total Modification Cost		$48,251
Total Cost		$51,385

New Development

Cost	$506,000
Weight	30 lb (13.6 kg)
Complexity	1.00
State-of-the-art factor	3
Data source	High-Rate Experiment - UV Grating Spectrometer

32-23-0761

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME Spectrophotometer - Beckman NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	COST $ MAT'L	LABOR	TOTAL
		Cover Slots in Sheet Metal w/Fine Stainless Screen	2	3.00		.20			4.00		
		Install Silicone Sponge Rubber Gasket Around Knob Holes	6	1.50	.50	.30			5.00		
		Adapt & Install 2 Detents	2	1.20	.30	.25			14.90		
		Fab. & Install Silocone Sponge Rubber Gasket For PB's	1	1.00	.25	.15			3.00		
		Fab. & Install Lexan Cover	1	1.00	.25	.10			18.00		
		Replace Bottom Cover with Aluminum Plate	1	2.50	1.00	.20			25.00		
		Fab. & Install Dress Edges	8	8.00	4.00	1.00			24.00		
		Fab. Corner Pieces	9	9.00	3.00	.50			13.50		
		Replace & Fab. Knobs & PB's	9	9.00	1.00	.75			250.00		
		Adapt IB for Rack Mount	1	3.00	1.00	.25			25.00		
		Fab. & Assemble Slitarm assy	1	1.00	.50	.25			12.50		
		Fab. & assy. Down Block assy	1	6.00	1.50	.50			20.00		
		Fab. Forked Rod Assy.	1	2.00	.50	.25			5.00		
		Modify Case for Above		1.00					2.00		
		Modify & Install Studs & Nut	1	1.00	.25	.10			2.50		
		Fab. 3 Parts to Replace Arm	1	5.00	.25	.50			5.00		
		Motor Support	2	2.20	.20	.20			5.00		
		TOTAL HOURS									

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LOT SIZE FROM	TO	RATE
		O.H.
		TOTAL
		TOTAL
		TOTAL

SHEET 1 OF 3 BY STATA

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SD 74-SA-0047-3

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME Spectrophotometer - Beckman NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD.			COST $ MAT'L	LABOR	TOTAL
		Vespel Clips 1/2 cu. in. ea	18	9 00		90							12 50		
		Modify Instrument for Above		12 00	3 00	1 20							3 50		
		Fab. Card Guides - Double	2	6 00		30							10 00		
		Fab. Card Guides - Single	6	12 00		60							45 00		
		Fab. Capacitor Support	1	3 00	1 00	20							10 00		
		Nixietube Support Bracket		3 00	2 00	20							10 00		
		50% Contingency Per "E"		31 60	4 60	2 60							177 75		
		EMI - Line Filter											33 50		
		Remove Press Tape			25	05									
		Conformal Coat Transformer			1 00	10							3 00		
		Strip & Replate Cad parts											180 00		
		Rewire w/TFE Wire			80 00	40 00		80 00					60 00		
		Fab. Plenium Chamber w/Fan		10 00	8 00	1 00	20 00	10 00					75 00		
		Items required for Performance of Part One Items:													
		Completely Dissassemble Instrument			40 00			80 00	80 00						
		Identify & Replace all Card Hardware w/SS						10 00	30 00	10 00			40 00		
		Reassemble & Inspect			80 00	40 00	20 00	15 00	80 00				20 00		
		Test Per Original Spec.				40 00	40 00								
		General Misc. Support				10 00		30 00	10 00	30 00			30 00		
		Replace Foam on Lid							2 50				4 00		
		TOTAL HOURS													

LOT SIZE FROM	LOT SIZE TO	RATE
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		TOTAL
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Beckman INSTRUMENTS, INC.

SHEET 2 OF 3 BY STATA

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MANUFACTURING COST ESTIMATE

52-73-07.1

ASSEMBLY NO. ______ ASSEMBLY NAME Spectrophotometer - Beckman NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD.		COST $: MAT'L	LABOR	TOTAL
		Add NYLOC Feature to Hard-ware										35.00		
		150 Hour Bake Out						16.00				500.00		
		Fab.	1	1.50		.50			3.00			5.00		
		Fab.	1	1.00		.25			1.00			2.50		
		Conformal Coat PCB	12		15.00	2.40						36.00		
		Pin 7 Knobs	7	3.50		.35								
		TOTAL HOURS		150.00	249.00	146.05	80.00	241.00	206.50	40.00		1973.15		

Beckman INSTRUMENTS, INC.

SHEET 3 OF 3 BY STATA

LOT SIZE FROM	LOT SIZE TO		MAT'L	LABOR	TOTAL
		RATE			
		O.H.			
		TOTAL	1973.15	15162.31	17135.46
		TOTAL			
		TOTAL			

2-296

SD 74-SA-0047-3

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2.22.7 EC006M Delta Modification Requirements Summary

1. Provide for non-operating vacuum and thermal capability.
   a. Respecify and replace 100 electronic parts for vacuum and temperature.
   b. Replace lubricants in fan motor, optics motor, linkages and counter.
   c. Provide vacuum and thermal test chambers (not now utilized) and test time for qualification and acceptance testing.
2. Provide connector interface for all item-level testing.
   a. Add an external interface connector (50-pin).
   b. Add a 50-wire test harness.
   c. Patch wire 8 PCB's to spare PCB connector pins (approximately 4 wires each).
   d. Add a hardmounted signal isolator circuit board (40 discretes).
3. Provide connector/wire junction moisture sealing.
   a. Eight PCB-to-master board connectors (printed pins on PCB's).
   b. Ten 3-to-15 pin molded assembly-to-harness connectors.
   c. Three item interface connectors.
4. Replace PVC as follows (delta to SEEIR modifications):
   a. Fifty loose wires not in harnesses.
5. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**
6. Human Factors
   a. Reorient knob position lettering.
   b. Repackage internal assemblies for maintainability (approved screws, fasteners, test points, access, layouts, etc.).
   c. Provide front panel replaceable panel lamp (for maintainability).
   d. Add silkscreen operating instructions to panel (10 controls).
   e. Replace sample compartment door hinge with friction hinge.

2.22.8 Delta Modification Cost

Fabrication	$ 999	
Engineering	25,447	
Test	5,465	
Documentation	2,562	
Program Management	1,725	
Total delta modification cost		$36,197

2.22.9 Data Sources

1. Visual examination
2. Instruction Manual, Model 24 Spectrophotometer, Beckman Instruments

2.23 COMMERCIAL SPECTRUM ANALYZER

Manufacturer: Hewlett-Packard
Model Number: 141T, 8555A, 8552B, 8445A
Cost: $12,925

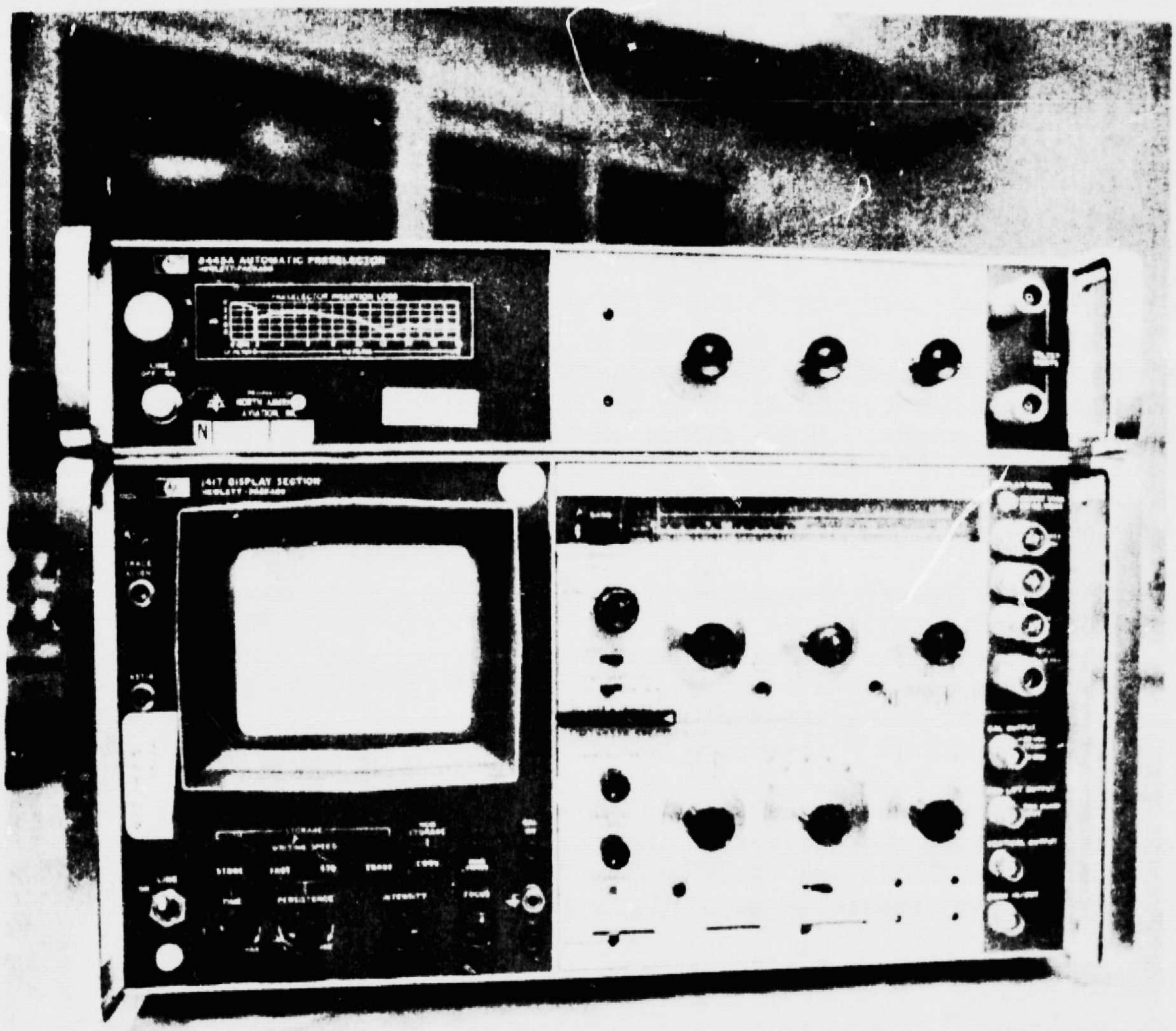

Figure 2.23-1. Hewlett-Packard Spectrum Analyzer With Automatic Preselector

2.23.1 Description

The Hewlett-Packard spectrum analyzer consists of three integral modules: (1) a display section, Model 141T; (2) a tuning section, Model 8555A; and (3) an IF section, Model 8552B); with a separate, automatic preselector, Model 8445A, mounted on top.

The Model 141T is designed for use as a display section for the HP Model 141T/8550-series plug-in spectrum analyzer. The instrument has variable persistence (duration of trace afterglow) and storage of CRT displays. Persistence is variable from 0.2 second to more than 60 seconds. A display can be stored (at reduced intensity) for more than 2 hours or displayed at normal intensity for up to 1 minute. Stored displays can be erased in 350 milliseconds.

The Model 141T uses a post-accelerator CRT with a non-glare rectangular faceplate. An internal graticule is located on the same plane as the display to eliminate parallax errors. The tube has a 9-kV accelerating potential, and 8 vertical by 10 horizontal divisions. A type P31 phosphor is used in the standard CRT.

The 8555A plug-in is the microwave RF section for use with the 8552-series IF section and the 140-series display section. Together they comprise a receiver that electronically scans an input signal and provides a visual display in the frequency domain. Input signal amplitude is plotted on the CRT as a function of frequency. The amplitude (Y-axis) of the CRT is calbrated in absolute units of power (dBm) or voltage (μV/mV) (50-ohm system): accordingly, absolute and relative measurements of both amplitude and frequency can be made.

The analyzer RF and IF sections form a super-hetrodyne receiver with spectrum-scanning capabilities over the frequency range of 10 MHz to 40 GHz in 14 frequency bands. The analyzer presents a calibrated CRT display up to 2 GHz wide. Absolute calibration accuracy is maintained from 10 MHz to 18.0 GHz in 10 frequency bands, using internal mixing. The frequency range from 12.4 GHz to 40 GHz is covered in 4 frequency bands through the use of external mixers.

The automatic preselector is an electronically tuned bandpass filter that automatically tracks the analyzer's tuning. Its purpose is to eliminate spurious, multiple, harmonic and image responses to avoid erroneous test results and to improve the dynamic range of the analyzer by about 30 dB.

2.23.2 Performance Characteristics

Cathode-Ray Tube

Type. Post-accelerator storage tube; 9000V accelerating potential; aluminized P31 phosphor; etched safety glass face plate.

Graticule. 8 x 10 divisions (approximately 7.1 x 8.9 cm) parallax-free internal graticule. Subdivisions of 0.2 div per major division on major horizontal and vertical axes.

Intensity Modulation. AC coupled, +20-volt pulse will blank trace of normal intensity; input terminals on rear panel.

Persistence

Variable. The standard writing speed mode is continuously variable from less than 0.2 second to more than one minute. Fast writing speed mode is typically variable from 0.2 seconds to 15 seconds.

Storage Time

Standard Writing Speed. More than two hours at reduced brightness (typically four hours). Traces may be viewed at maximum brightness for more than one minute.

Fast Writing Speed. Traces may be stored at reduced brightness for more than 15 minutes (typically 30 minutes) or stored at maximum brightness for more than 15 seconds.

Brightness

100 foot-lamberts in standard mode.

Frequency Range

Tuning Range. With internal mixer 0.01 to 18.00 GHz
With external mixer 12.4 to 40 GHz

Frequency Accuracy

Dial Accuracy. n x ($\pm$15 MHz) where n is the mixing mode

Scan Accuracy. Frequency error between two points on the display is less than 10 percent of the indicated separation.

Stability. Total Analyzer Residual FM (Fundamental Mixing)

Stabilized	Unstabilized
< 100 Hz peak-to-peak	< 10 kHz peak-to-peak

First LO residual FM typically 30 Hz

Noise Sidebands. For fundamental mixing. More than 70 dB below CW signal, 50 kHz or more away from signal, with 1 kHz IF bandwidth and 100 Hz video filter.

Resolution

Bandwidth Ranges. IF bandwidths of 0.10 to 300 kHz provided in a 1, 3 sequence.

Bandwidth Accuracy. Individual IF bandwidth 3 dB points calibrated to $\pm$20 percent. (10 kHz bandwidth $\pm$5 percent)

Bandwidth Selectivity

IF Bandwidth	60 dB/3dB Bandwidth Ratio (8552B)
10 kHz - 300 kHz	20:1
1 kHz - 3 kHz	11:1
0.1 kHz - 0.3 kHz	11:1

Amplitude - Absolute Calibration Range

Measurement Range

Log Reference Level: From -130 dBm to +10 dBm, in 10 dB steps. Log reference level vernier, 0 to -12 dB continuously.

Linear Sensitivity: From 0.1 μV/div to 100 mV/div in a 1,2 sequence. Linear sensitivity vernier 1 to 0.25 attenuation ratio continuously.

Sensitivity

Average Noise Level: Specified for 1 kHz bandwidth. Using lower bandwidths will improve average noise level; e.g., use of 100 Hz bandwidth will improve noise level in the 1.5 to 3.55 GHz frequency range from -117 dBm to -127 dBm max.

Display Range

Log: 70 dB, 10 dB/div with 8552B 2 dB/div log expand on a 16 dB display

Linear: From 0.1 mV to 100 mV/div in a 1,2 sequence on an 8-division display.

Input

Input Impedance. 50 ohms nominal (0.01 to 18 GHz)

Reflection Coefficient. $<$0.130 (1.30 SWR) for input RF attenuator settings $\geq$10 dB.

Maximum Input Level. Peak or average power + 10 dBM (1.0V ac peak) incident on mixer, +33 dBm incident on input attenuator.

Scan Time

Scan Time. 16 internal scan rates from 0.1 ms/div to 10 sec/div in a 1, 2, 5 sequence.

Scan Time Accuracy. 0.1 ms/div to 20 ms/div, $\pm$10 percent, 50 ms/div to 10 sec/div, $\pm$20 percent.

2.23.3 Physical Characteristics

Dimensions

Model 141T Display Section

9-1/16 in. high (including height of feet) x
16-3/4 in. wide x 18-3/8 in. deep (22.9 x
42.5 x 46.7 cm)

The preselector is approximately 4 in. [illegible]

Weight

Model 8555A RF Section: Net, 14 lb 15 oz (6,8 kg)
Model 8552A IF Section: Net, 9 lb (4,1 kg)
Model 141T Display Section: Net, 40 lb (18 kg)
Model 8445A Preselector: Net,

2.23.4 Suitability Analysis

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. Modular construction. Display section contains CRT and space for RF and IF modules. Construction of heavy guage aluminum. RF section built extreuely sturdy (see Figure 2.23-2). Heavy aluminum castings enclose electronics. Preselector has high frequency waveguides traversing rear of unit (Figure 2.23-3). Remaining units are more typical electronic instrument-type construction. Unit can be obtained in rack mount configuration; however, weight justifies additional support structure.			
MATERIALS			
Glass			
Aluminum			
Plastic knobs			
Brass			
PVC wire insulation			
Phosphorous			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Heat sink/fan assembly requires shock mounts			X
Large capacitors beside CRT require additional support (Figure 2.23-4)			X
Rotary switch assembly of RF module requires additional support			X
Circuit boards of IF module require additional support (Figure 2.23-5)			X
All structural fasteners require positive retention			X
Wave guide in automatic preselected requires additional support			X
Push on transistor radiator fins requires positive retention			X
Large capacitor in preselector requires support			X
ELECTRICAL POWER			
Power Requirements: 100, 120, 220 or 240 volts (+5 to -10%), 48 to 440 Hz, normally less than 285 watts (varies with plug-in units)	X		
	X		

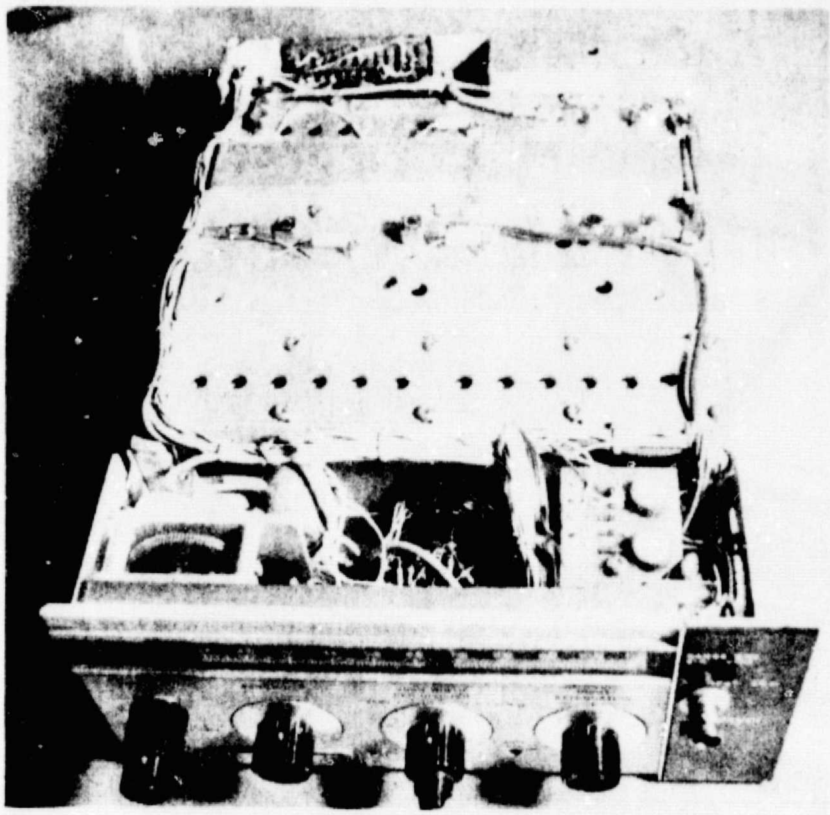

Figure 2.23-2.

8555A RF Section Construction

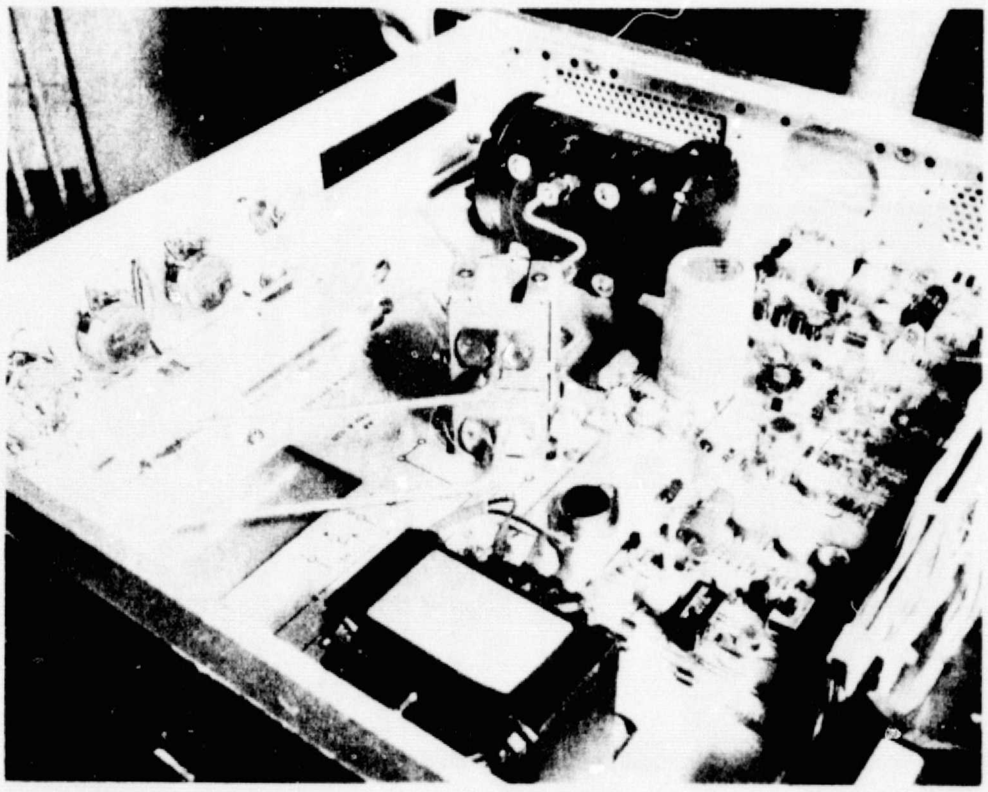

Figure 2.23-3. Interior of Preselector

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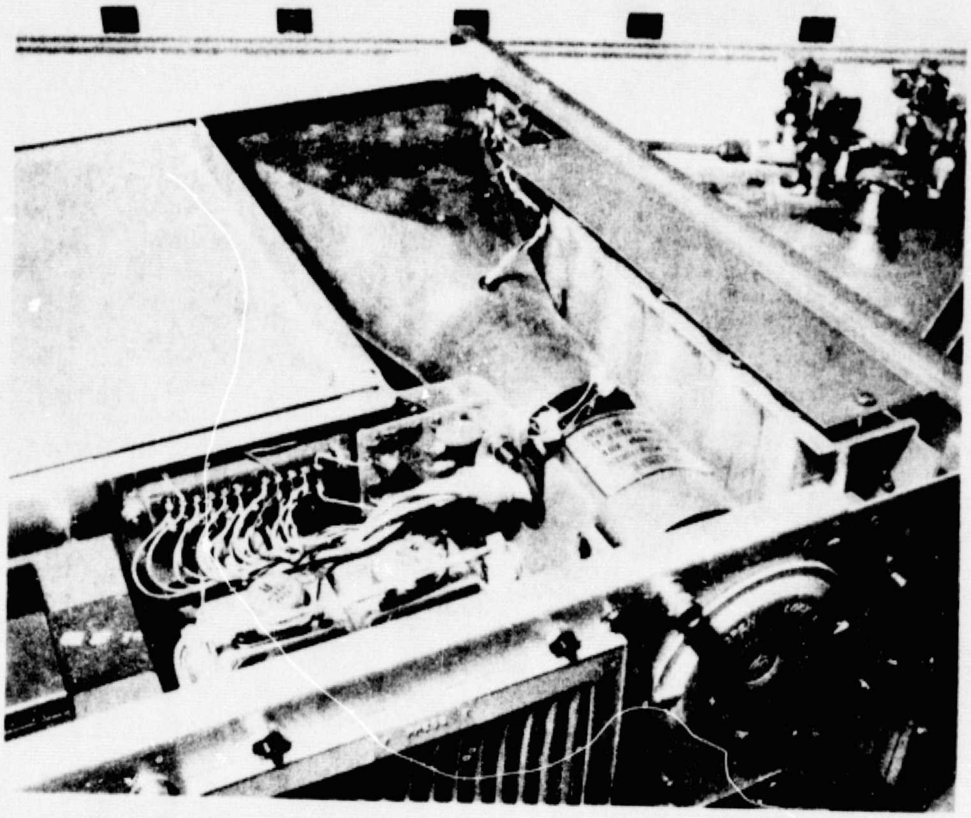

Figure 2.23-4. Display Section Interior Showing Capacitors Requiring Additional Support

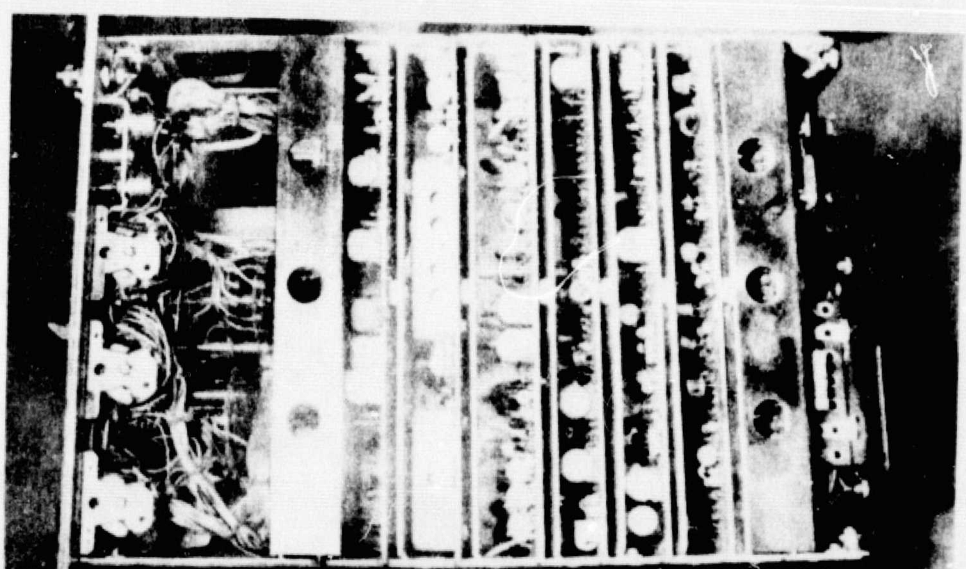

Figure 2.23-5. Interior of IF Section

	Disposition		
	Accept	Verify	Unaccept
DATA MANAGEMENT COMPATIBILITY			
Vertical Output: Approximately 0 to -0.8 V for 8-division deflection on CRT display, approximately 100 Ω output impedance.	X		
Scan Output: -5.0 to +5.0 V for 10 div CRT deflection, 1 kΩ output impedance.			
Pen Lift Output: 0 to 14 V (0 V, pen down). Output available in Int and Single Scan modes and Auto, Line and Video scan trigger.			
EMI SUSCEPTIBILITY AND RADIATION			
EMI: Conducted and radiated interference is within requirements of MIL-I-16910C and MIL-I-6181D and methods CE03 and RE02 of MIL-STD-461 (except 35 to 40 kHz) when 8553B and 8552 are combined in a 140T or 141T Display Section.	X		
Signal returns grounded to chassis via BNC connectors and circuit boards.			X
NOISE GENERATION			
Cooling fan noise exceeds 40 db			X
FLAMMABILITY			
Plastic knobs			X
PVC wire insulation			X
TOXICITY			
No prohibited toxics or large quantities of unidentified potential generators identified	X		
CONTAMINATION GENERATION			
CRT and fuses can shatter and escape unit			X
ATMOSPHERE			
Compatible with Spacelab atmosphere	X		

Item	Accept	Verify	Unaccept
AMBIENT TEMPERATURES			
Temperature Range: Operating, 0 C to +55 C; storage, -40 C to +75 C	X		
EQUIPMENT COOLING			
Has internal fan for forced air cooling	X		
ZERO-G EFFECTS			
No gravity dependent functions	X		
OPERABILITY			
Handle guards have sharp edges			X

2.23.5 Modifications

Construction

Shatterables. Due to glass components (CRT and fuses) cover inside of venting with fine mesh screen.

9-G Mounting. Attach 19-inch rack-mounting flanges supplied with unit. Install taper-pin support assemblies to lower rear panel of mainframe, and mating guide rails inside rack cabinet per paragraph 10.0 of Design Guidelines.

Protrusion Protection. Install protection rails on rack cabinet per paragraph 12.0 of Design Guidelines.

Shock and Vibration.

1. Install heavy duty shock mounts for heat sink/fan assembly on rear panel.
2. Secure large capacitors near CRT per Figure 2.23-6. Secure capacitor in preselector similarly.
3. Secure rotary switch per Figure 2.23-7.
4. Dampen circuit board vibration per Figure 2.23-8.
5. Replace all structural fasteners per paragraph 6.0 of Design Guidelines.
6. Secure waveguides per Figure 2.23-9.
7. Secure push-on radiator fins to transistor in Preselector Unit with epoxy adhesive.
8. Vibration-proof screws, knobs, etc.

Acoustics. Replace cooling fan assemblies with those of a suitable acoustic level.

Materials Usage

1. Replace plastic knobs with custom-fabricated Vespel articles.
2. Provide 150-hour off-gas bakeout.
3. Remove existing wiring and replace with wires having a suitable insulation material (approximate number of wires: 650).
4. Conformally coat circuit boards.

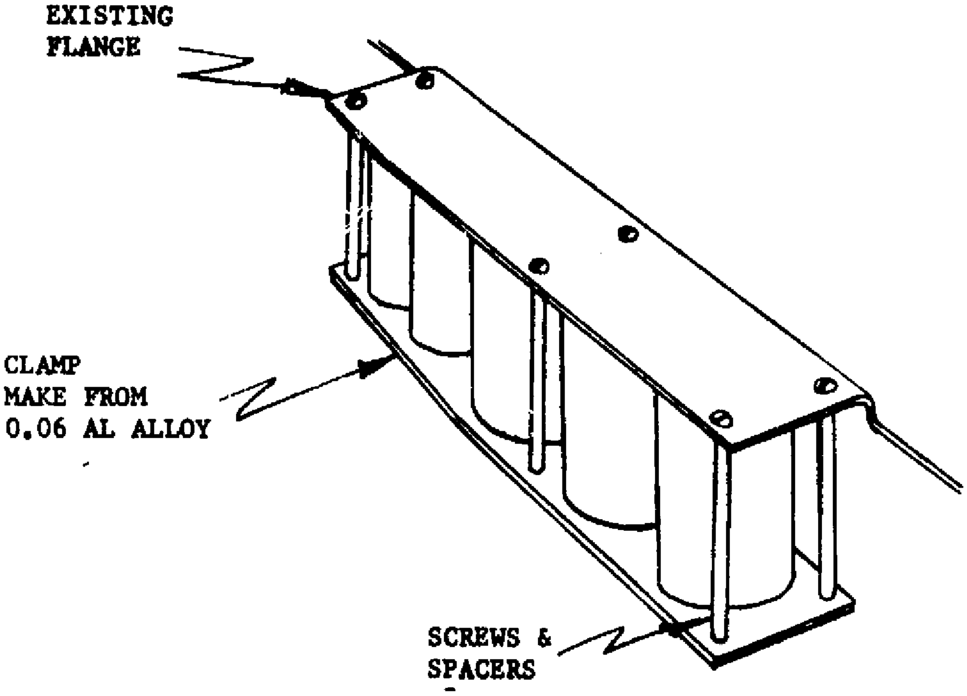

Figure 2.23-6. Capacitor Securing

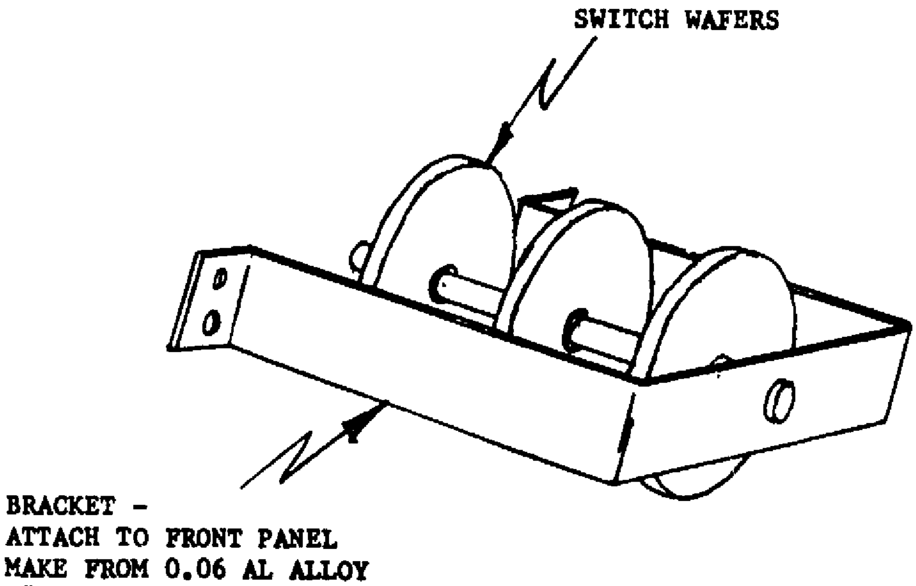

Figure 2.23-7. Rotary Switch Securing

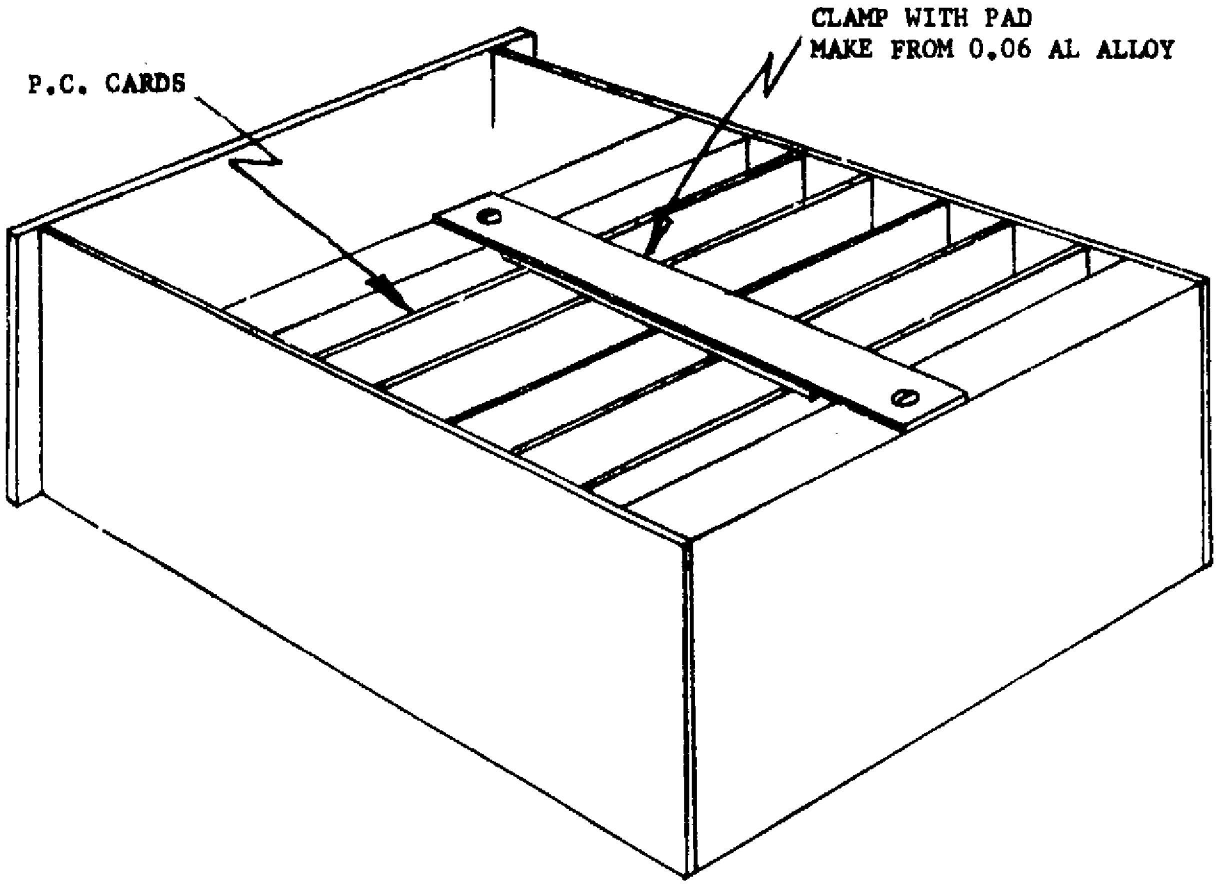

Figure 2.23-8. Printed Circuit Board Securing - IF Section

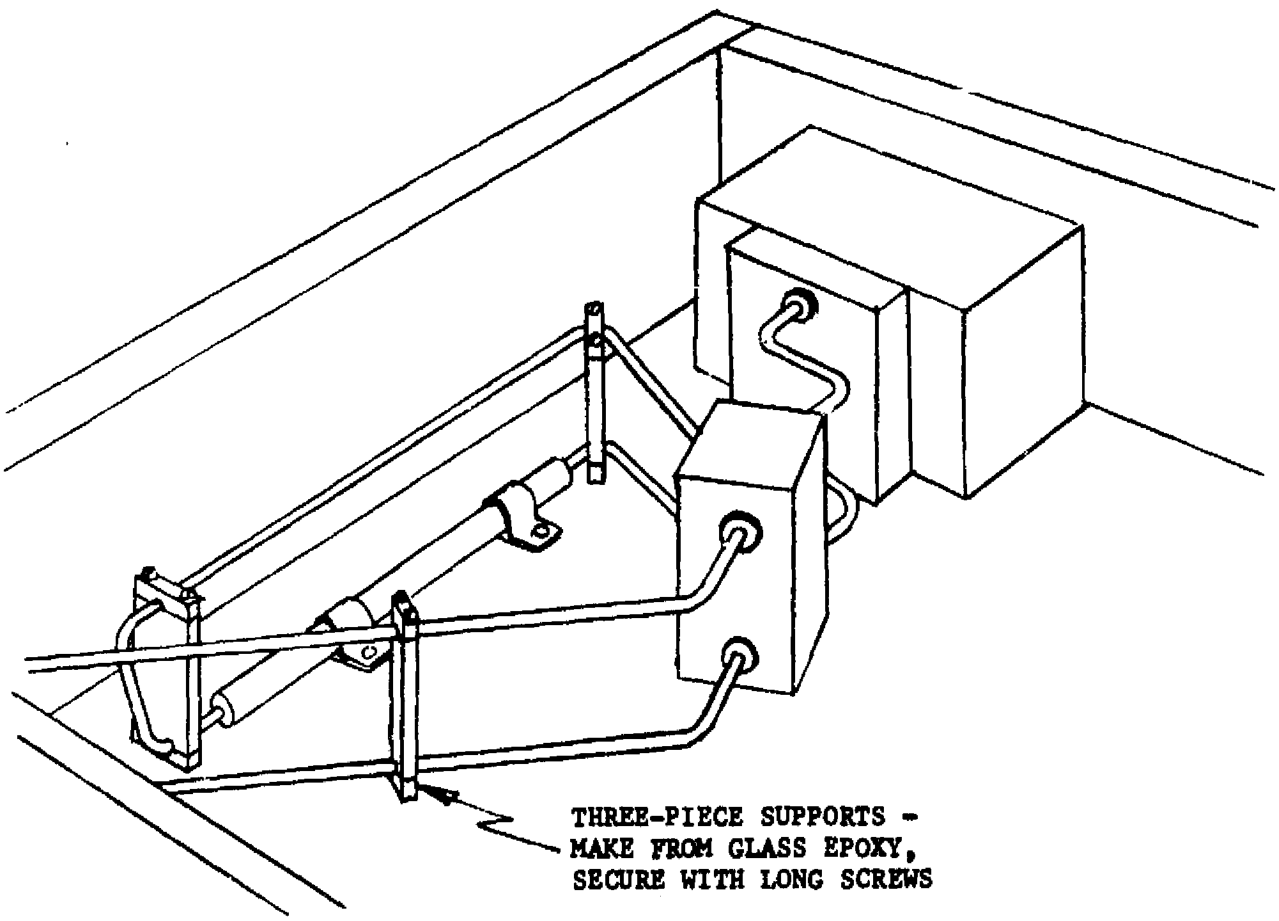

Figure 2.23-9. Waveguide Supports - Automatic Preselector

2.23.6 Cost Analysis

Modification

Basic Cost		$ 15,000
Modification Cost		
Fabrication	$ 7,891	
Engineering	17,056	
Test	4,416	
Documentation	2,160	
Program Management	1,576	
Total Modification Cost		$ 33,099
Total Cost		$ 48,099

New Development

Cost	$ 516,000
Weight	40 pounds
Complexity	1.0
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter Communications

2.23.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum (only) capability (from current 1.6 psia)

   a. Provide chamber and test time for qual and acceptance

   b. Respecify and replace 160 electronic parts for vacuum

   c. Replace lubricant in fan motors (2 each)

2. Provide connector interface for item level testing

   a. Add 50-pin interface connectors in 141T unit

   b. Add 50-wire test harness in 141T unit

   c. Patch wire 7 PCB's and 8552, 8555, and 8445A signals to spare connector pins (approximately 5 wires per unit)

   d. Add test signal isolation circuit board (hardmount) (20 discretes)

3. Provide connector/wire junction moisture sealing

   a. 8 interface connectors (for all 4 units)

   b. 20 PCB connectors (printed pin)

   c. 1 terminal board

52-43-07.1

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ____ ASSEMBLY NAME Spectrum Analyzer NEXT ASSY NO. ____ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	FAB	ASS'Y	INSP.	TEST	M.E.	EXPED	MAT'L	LABOR	TOTAL
		Screen Vents assy. Fine Mesh		3 50		15				5 50		
		Install Flanges	2		50	05						
		Fab. GUide Pins & Rails	2	3 50	1 00	20				22 50		
		Fab. Protection Rails	2	2 00		20				10 00		
		Fab. Heavy Duty Shock Mounts		8 00	2 00	80				20 00		
		Fab. Cap Brackets	1	2 50	1 00	25				3 00		
		Fab. Bracket	1	1 00	1 00	15				1 50		
		Fab. PCB Bracket	1	1 00	15	10				1 50		
		Replace Fasteners x	200		30 00	20 00	40 00	40 00		50 00		
		Fab. Supports	3	2 00	1 50	75		1 00		9 00		
		Epoxy Trans Heatsinks x	100		3 00	60				12 00		
		VIB Proof. Knobs & Screws	AR	3 00	1 50	60				9 00		
		Replace Fan	2	8 00	3 00	2 00	4 00	2 00		250 00		
		Fab. Vespel Knobs	30	30 00		3 00				750 00		
		150 Hour Bake						16 00		500 00		
		Rewire with TFE	650		20 00	3 00		12 00		20 00		
		Conformal Coat PCB's	8		17 00	3 00				24 00		
		Support of Above Items				8 00		40 00	20 00			
		Test & Recalibrate				30 00	50 00					
		TOTAL HOURS		65 50	119 65	79 95	94 00	139 00	20 00	1688 00		

[redacted] INSTRUMENTS, INC.

LOT SIZE FROM	LOT SIZE TO		MAT'L	LABOR	TOTAL
		RATE			
		O.H.			
		TOTAL	1688 00	7159 06	7390 50
		TOTAL			
		TOTAL			

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d. 5 external interface connectors

4. Replace PV as follows (delta to SEEIR mods)

   a. 175 loose wires

5. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

6. Human factors mods

   a. Add captive 1/4 turn panel mount fasteners (6)

   b. Add silkscreen operating instructions on panels (22 controls)

2.23.8 Delta Modification Costs

Fabrication	$ 1,727	
Engineering	35,530	
Test	5,851	
Documentation	2,562	
Program Management	2,284	
Total delta modification cost		$ 47,954

2.23.9 Data Sources

1. Visual examination

2. 5952-1105. Spectrum Analyzer 1 kHz to 110 MHz, Models 8553B, 8443A/B, Hewlett Packard.

3. HP 8552B, Operating and Service Manual, Spectrum Analyzer, IF Section, Hewlett Packard.

4. HP141T, Operating and Service Manual, Display Section, Hewlett Packard.

5. HP8555A, Operating and Service Manual, Spectrum Analyzer RF Section, Hewlett Packard.

6. 1973 Hewlett Packard Electronic Instruments and Systems for Measurement/Analysis/Computation

2.24 FREQUENCY SYNTHESIZER

Manufacturer: Fluke
Model Number: 645M
Cost: $17,200

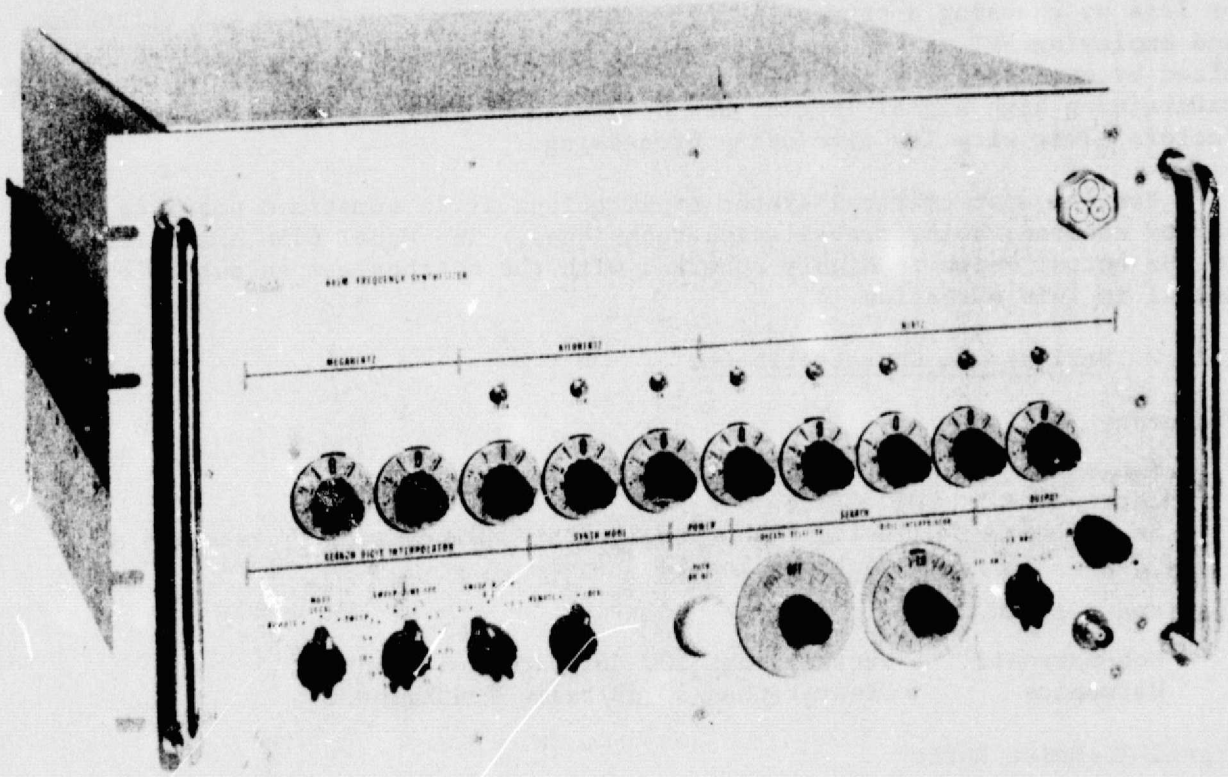

Figure 2.24-1. Fluke Mil-Spec Frequency Synthesizer (Model 645M)

2.24.1 Description

A coherent frequency synthesizer is a device which produces an output frequency which is related to an input frequency by the ratio of two integers. The Model 645M is such a device, in which the output frequency is directly derived from a 5 MHz reference input through a process involving frequency multiplication, division and translation only. The output frequency covers the 0 to 50 MHz range in .01 Hz steps and the frequency may be either manually or electrically selected. A search oscillator allows interpolation between steps or continuous frequency variability of up to $\pm$100 kHz symmetrically around the selected synthesized frequency.

During development of the 645M utmost attention was given to minimizing contaminates in the output. Discrete spurious signals were held to -100 dB or less by choosing a prudent number scheme, careful packaging and filtering, and employing FET mixers in critical circuits. The noise content was minimized by employing low noise figure circuits, carefully distributing gain, maintaining high signal levels, and utilizing low synthesis multiplication factors along with low time delay processing.

For the most critical system applications it is sometimes possible to employ coherent noise cancellation techniques. The Model 645M has a fixed 10 MHz output which is highly coherent with the synthesizer output which is useful in this situation.

2.24.2 Performance Characteristics

Frequency

Range	dc to 50 MHz
Increments	0.01 Hz
Selection	Using front panel rotary switches or by remote contact closure

Spurious Outputs

Non-Harmonic	Greater than 100 dB below fundamental
Harmonics	Greater than 30 dB below fundamental

Signal-To-Noise Ratio

Including the effects of the internal standard		Measured in a 30 kHz band excluding a 1 Hz band centered on the fundamental. Valid for dialed frequencies from 1 MHz to 50 MHz.
Phase	Greater than 66 dB	
Amplitude	Greater than 86 dB	
Synthesizer residual (Internal noise from 5 MHz input to synthesizer output)		
Phase	Greater than 78 dB	
Amplitude	Greater than 88 dB	

Residual Phase Noise Spectral Density	SSB S/N ratio from 5 MHz input to synthesizer output measured in a 1 Hz bandwidth. Valid for dialed frequencies from 1 MHz to 50 MHz.

Offset Frequency	Minimum S/N
20 Hz	104.6 dB
200 Hz	116.6 dB
5 kHz	129.9 dB
50 kHz	132.0 dB

Output Voltage	
50 Hz to 50 MHz	Adjustable from 0.2 to 1.0 VRMS into 50-ohm with Auto-Level-Control (ALC) by front panel control or external dc voltage. ALC control maintained from 20 kHz to 50 MHz at 1.0 VRMS ±0.25 dB into 50 ohms, 25 C ambient. 1.0 VRMS ± 1 DB into 50 ohms (ALC disabled). Spectral specifications are valid at 1.0 VRMS into 50 ohms with or without ALC.
dc to 100 kHz	100 mv RMS ±2 dB into 50 ohms.
Amplitude Modulation	Both outputs capable of external modulation to 50 percent from dc to 10 kHz rate.
Switching Time	Less than 20 usec for output amplitude to be with ±1 dB of final value and phase to be within ±0.1 radian at its new frequency (without ALC).
Search Oscillator	Continuous adjustment about selected synthesized signal with range of ±0.01 Hz to ±100 kHz selectable in decade steps by front panel or remote contact closure.
Local Search	Calibrated front panel control.
Remote Search	Programmable by external resistance of voltage of -10 volts to +10 vdc.
Accuracy	±2 percent of range at 25 C; ±5 percent of range at 0 to 55 C.
Frequency Modulation	May be modulated up to 1 kHz rate.
Internal Sweep Generator	Internal triangular waveform with nominal half-period of 10 ms to 50 sec in 1, 2, 5 sequencies. Sweep width adjustable to nominally 100 percent, 50 percent and 20 percent of decade selected. Waveform available on rear connector.
Synthesizer Input Frequency	5 MHz
Auxiliary Outputs	5 MHz to 10 MHz at nominally 1 VRMS into 50 ohms.

2.24.3 Physical Characteristics

Dimensions and Weight

Standard 19 in. (48.3 cm) relay rack width 10-1/2 in. (26.7 cm) high, 23-5/8 in. (60.0 cm) behind front panel, 91 pounds (41.4 kg). Slides and rack mounting kit are included.

2.24.4 Suitability Analysis

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. Heavy rack mounted unit. Electronics located in metallic modules.			
MATERIALS			
PVC ribbon cable Plastic knobs Styrafoam			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Shock. Unit will conform to MIL-S-901C, Amendment 1, Grade A High Impact Shock Test which is referenced by paragraph 3.11.8.1 of MIL-E-16400F, Amendment 5. The instrument may momentarily experience output signal interruption during high impacts.	X		
Vibration. Meets requirements of MIL-STD-167, Type 1 Environmental Vibration which is referenced by paragraph 3.11.8.2 of MIL-E-16400F, Amendment 5. During vibration, phase noise spectral characteristics are slightly degraded.		X	
Wires well tied down	X		
Shielded compartments well supported	X		
Connector covers should be removed since no positive retention			X
ELECTRICAL POWER			
100/115/200/230 VRMS $\pm 10\%$ selectable by internal jumpers, 50-400 Hz, 125 watts maximum	X		
DATA MANAGEMENT COMPATIBILITY			
Only 1 VRMS into 50 ohm output		X	
EMI SUSCEPTIBILITY AND RADIATION			
Unit will conform to MIL-STD-461-A Class 1D which is referenced by paragraph 3.9.4 of MIL-E-16400F Amendment 5.	X		
FLAMMABILITY			
Unit is sealed	X		
Plastic knobs			X

Item	Disposition: Accept	Verify	Unaccept
TOXICITY			
Sealed unit	X		
ATMOSPHERE			
Humidity. Operations, as described in paragraph 3.8.2 of MIL-E-16400F, Amendment 5, is possible at relative humidities ranging up to 95% for both continuous and intermittent periods, including conditions wherein condensation takes place in and on the equipment in the form of both water and frost.	X		
AMBIENT TEMPERATURES			
Temperature. Unit will perform in accordance with 3.8.1 of MIL-E-16400F, Amendment 5, Class 4. Temperature ranges are as follows: Operating - 0 to +50 C Non-operating - -62 C to +75 C	X		
EQUIPMENT COOLING			
Has external convector plates requiring installation in forced air rack (see Figure 2.24-2)	X		
ZERO-G EFFECTS			
No gravity dependent functions	X		
OPERABILITY			
Additional protrusion protection required			X

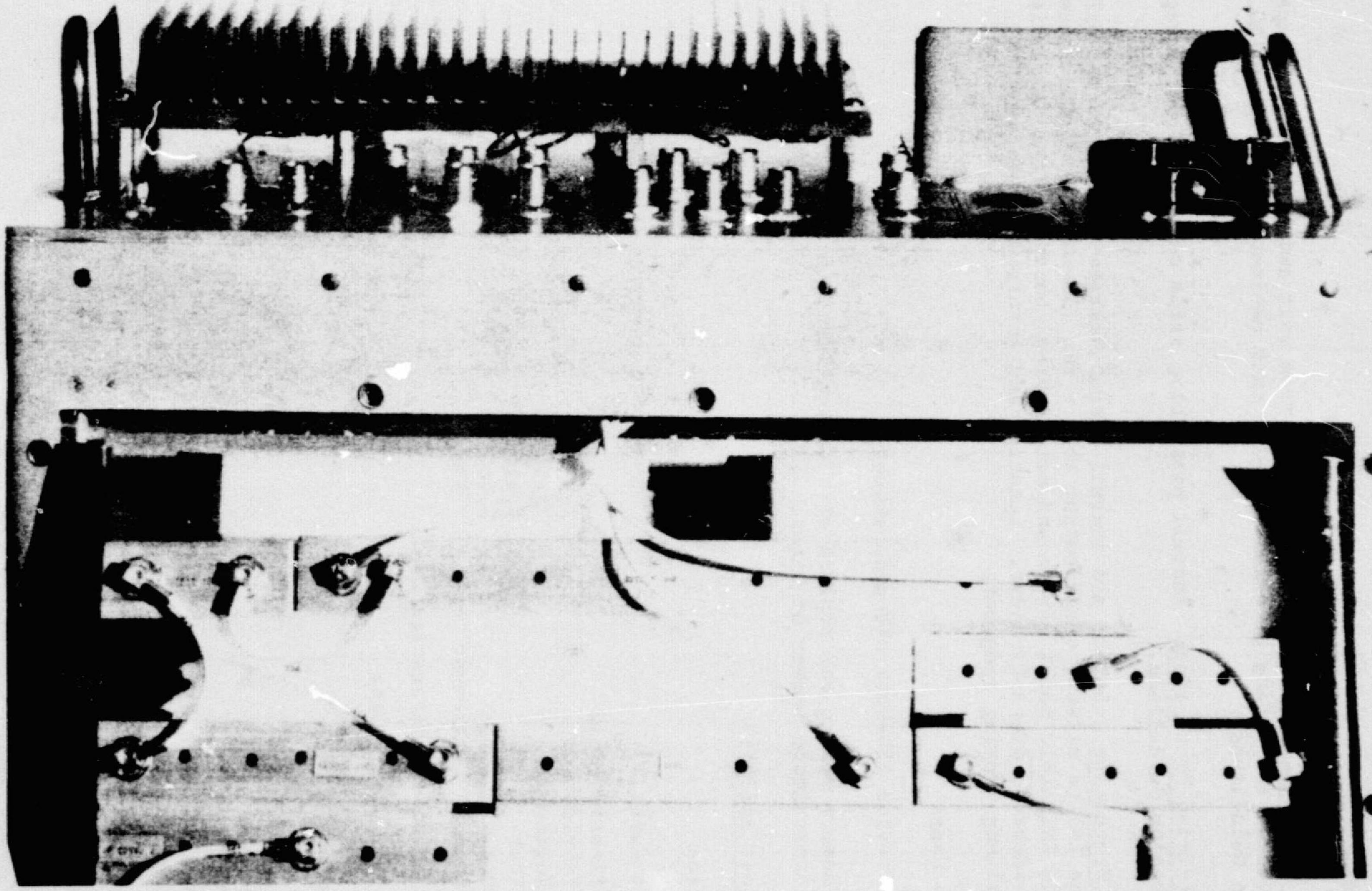

Figure 2.24-2. Rear of Fluke Frequency Synthesizer

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2.24.5 Modifications

Construction

9-G Mounting. Remove existing slides from unit and replace with taper-pin assemblies and mating guiderails inside rack cabinet per paragraph 10.0 of Design Guidelines.

Protrusion Protection. Install protection rails on cabinet per paragraph 10.0 of Design Guidelines.

EMI Protection. Select and install output voltage amplifier (approximate size: one IC) to raise 1 v rms output to 5 v rms (50-ohm output impedance) to provide EMI cable noise margin and data system compatibility. Amplifier must be wideband, distortionless. Location and interconnect to be per electrical engineering judgment.

Materials Usage

1. Provide 150-hour off-gas bakeout
2. Remove wiring and replace with teflon insulated wires. Approximate number of wires: 120.

2.24.6 Cost Analysis

Modification

Basic Cost		$ 19,747
Modification Cost		
Fabrication	$ 2,941	
Engineering	7,250	
Test	4,416	
Documentation	2,160	
Program Management	838	
Total Modification Cost		$ 17,605
Total Cost		$ 37,352

New Development

Cost	$ 452,000
Weight	35 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter Communications

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. Fluke 645 M ASSEMBLY NAME Frequency Synthesizer NEXT ASSY NO. ______ DATE __/__/__

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	Mfg Tech	COST $: MAT'L	LABOR	TOTAL
		Remove Slides from Unit			50							
		Fab. Rack Mount Per Design Guide	1	3 50	1 00	20				22 50		
		Fab. Prutrusion Protection	2	2 00		20				10 00		
		Select & Install Volt Amp	1	1 00	2 00	1 00	8 00	4 00	4 00	54 00		
		150 Hour Gas Bake						16 00		500 00		
		Remove & Replace Wiring w/TFE	120		10 00	8 00		8 00	18 00			
		System Support w/TFE		5 00	10 00	8 00	4 00	8 00	8 00	50 00		
		Test & Recalibrate				4 00	30 00					
		TOTAL HOURS		11 50	23 50	21 40	42 00	36 00	30 00	636 50		

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			TOTAL	636 50	2304 15	2940 65
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			TOTAL			

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Space Division Rockwell International

2.24.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal range capability
   a. Respecify and replace 200 parts (10 IC's) for vacuum/thermal
   b. Add test chambers and test time for qual and acceptance
2. Provide external interface connector to test item to replaceable assembly level
   a. Add two 50-pin external interface connectors
   b. Add a 100-wire test harness to 30 modules
   c. Add a hardmount test signal isolation PCB (40 discretes)
3. Seal the following connectors/wire junctions against moisture
   a. 15 external interface coax connectors
   b. 1 external interface connector
4. Replace PVC as follows (delta over SEEIR mods)
   a. 4 harnesses (60 wires)
   b. 100 loose wires
5. Human factors mods as follows
   a. Add panel captive 1/4 turn fasteners (4 places)
   b. Add silkscreened operating instructions on panel (18 controls)
6. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

2.24.8 Delta Modification Costs

Fabrication	$ 1,524	
Engineering	34,481	
Test	5,851	
Documentation	2,562	
Program Management	2,209	
Total delta modification cost		$ 46,627

2.24.9 Data Sources

1. 1973 Catalog - Test and Measurements Instruments, John Fluke Mfg. Co., Inc.
2. Photographs provided by John Fluke Mfg. Co., Inc.

2.25 WAVE ANALYZER

Manufacturer: Singer

Model No.: SSB-50-1

Cost: $7000

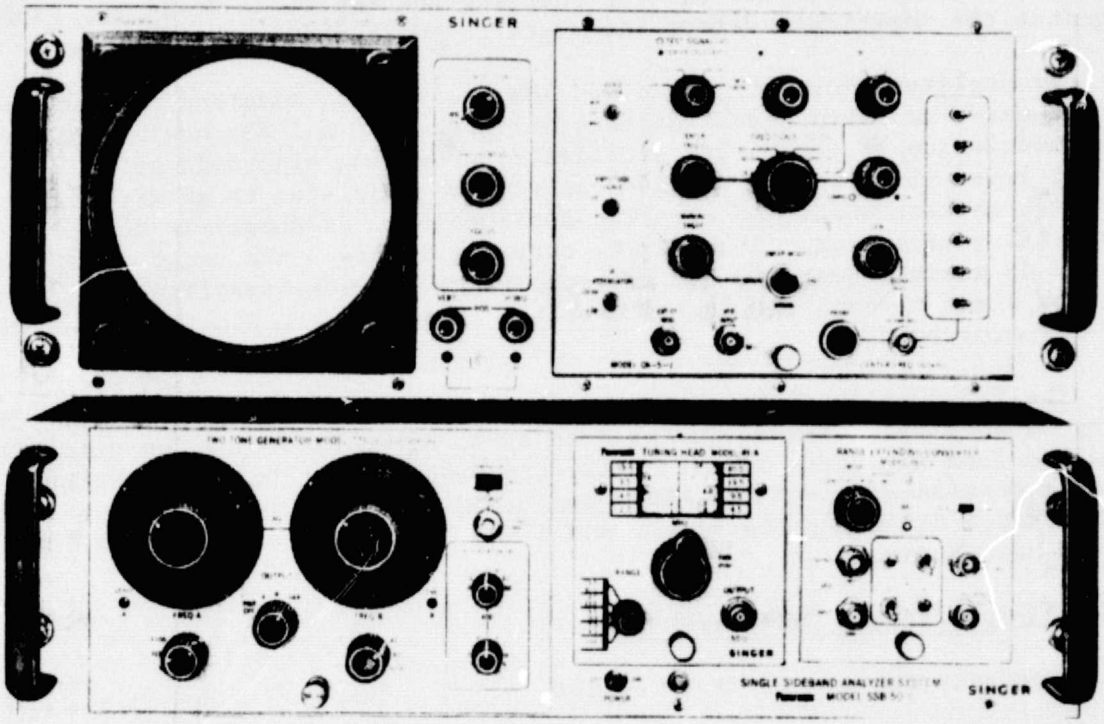

Figure 2.25-1. Singer Wave Analyzer - Model SSB-50-1

2.25.1 Description

This analyzer incorporates all needed analysis facilities to set up, adjust, monitor, and trouble-shoot SSB and other transmissions. The vast majority of spectrum tests on single sideband and other communications systems can be performed using only these units. Internal crystal controlled marker signals check, the accuracy of readings. The tuning head includes a direct reading frequency scale which can be covered by 24 knob rotations with fast "search" tuning. Fine tuning rate is 16 times slower. Tuning head stability better than 0.005 Hz/MHz/sec after warm-up enables jitter-free measurements with 10 Hz selectivity to 40 MHz and with slight de-rating to above 200 MHz.

A 500 kHz crystal controlled oscillator is provided for setting the center frequency of the analyzer and for checking the amplitude scale calibrations against the input attenuators (accurate to ±0.05 db/db).

By amplitude modulating the 500 kHz oscillator, sideband pips are generated which serve as sweep width (dispersion) markers. A 5 kHz oscillator is furnished for modulation of the marker oscillator, providing sidebands at ±5 kHz intervals to at least ±50 kHz. The marker can also be modulated by an external source to provide markers suited to specific applications. Accuracy is determined by the external source used. Sensitivity over the 10 Hz-40 MHz range is within ±3 db, ± 1/2 db maximum over any 100 kHz scan range. Sweep stability is achieved on narrow scans through the use of a stable LC oscillator and the jitter free RF-8 tuning head.

The SSB-50-1 consists of two main frames--the MF-5 and MF-50 and four plug-in modules: CA-5-1, Tuning Head RF-8, Range Extending Converter REC-2, and Two-Tone Generator TTG-3. Fully transistorized, the CA-5-1 occupies the module section of the Model MF-5 Main Frame. The Model RF-8 Tuning Head, REC-2 Range Extending Converter, and TTG-3 Two-Tone Generator plug into the MF-50 Main Frame.

2.25.2 Performance Characteristics

Frequency range - 10 Hz to 40 MHz

Image rejection - better than 40 dB for 500 kHz IF

Sensitivity - 5 microvolts from 2 MHz to 40 MHz and 15μV input from 10 Hz to 2 MHz produces at least a full-scale LIN deflection on the CRT. Minimum measureable signal (approximately 0.5 microvolts) produces at least a one-division LIN deflection on the CRT.

Sweep Width - preset: 150 Hz, 500 Hz, 3.5 kHz, 7 kHz, and 14 kHz. Variable: 0 to 100 kHz

Sweep Rate - 0.1 Hz for 150- and 500-Hz preset sweep widths (can be increased to 1 Hz with front panel control); 1 Hz for 3.5-, 7-, and 14 kHz preset sweep widths; and 0.1 to 30 Hz for variable sweep width; or manually controlled.

Resolution (3 db down) - 10 Hz to 3 kHz adjustable. Automatic optimum resolution for the 5 preset ranges, with 50 Hz skirt selectivity at -60 db point for 150 Hz preset sweep width.

Dynamic Range - All in-band (odd order) intermodulation products at least 70 db down from single tone level in two-tone test.

Response Flatness - Overall: better than ±1 db, 10 Hz -2 Mhz. Better than ±2 db, 2 MHz -40 MHz. In-band: better than ±0.5 db.

Input Impedance - 50 or 600 ohms (switch slectable), 10 Hz to 2 MHz; 50 ohms, 2 MHz to 40 MHz; and 10 megohms, when optionally available PRB-50 probe is used.

Attenuators - Input: 0-70 db, in 1 db steps; accuracy 0.05 db/db, cumulative. IF: 20 db (±1 db).

Two-Tone Audio Test Signals

Frequencies: 20 Hz to 20 kHz, continuously adjustable

Frequency Accuracy: ±3 percent

Output Level: +10 dbm maximum into 600 ohms

Output Attenuators: 0-70 db in 1 db steps, accuracy 0.05 db/db

Distortion: All harmonics and IM products less than -66 db below single tone between 100 Hz and 10 kHz. Less than -60 db from 20 Hz to 100 Hz and 10 kHz to 20 kHz.

Amplitude Uniformity: ±0.5 db

Hum and Noise: Better than -66 db below single tone level

2.25.3 Physical Characteristics

Height - 12-7/32 inches (31.1 cm)

Width - 19 inches (48.3 cm)

Depth - 21-15/16 inches (behind front panel) (55.8 cm)

Weight - 62 pounds (28.2 kg)

2.25.4 Suitability Analysis

	Disposition: Accept	Verify	Unaccept
CONSTRUCTION. This heavy unit is completely enclosed. Electronics are in sealed modular boxes. Unit can be obtained in rack or bench mount.			
MATERIALS			
Plastic panel knobs Aluminum Glass CRT			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Uses thumb screws to hold in modules			X
Circuit board lead mounted parts not adequately supported			X
Large lead mounted circuit board capacitors in high voltage rectifier unit			X
MF-5 and MF-50 circuit boards (1 ea frame) not well supported			X
Electrolytic capacitor are well supported at base	X		
ELECTRICAL POWER			
Input power requirements: 95 to 130 volts or 190 to 260 volts (switch selectable), 50 to 400 Hz single phase.	X		
Power consumption: 50 watts maximum			
DATA MANAGEMENT COMPATIBILITY			
Has buffered, X-Y sync outputs for associate equipment		X	
MAINTAINABILITY			
Self-test Features:			
Two-tone test: Two crystal-controlled RF tones (3 MHz and 3.002 MHz) Calibrating oscillator: 500 kHz crystal-controlled oscillator for checking center frequency. Internal marker: 5 kHz oscillator modulates 500 kHz crystal-controlled oscillator to provide 5 kHz markers for sweep width calibrations to 100 kHz.	X		

	Disposition		
	Accept	Verify	Unaccept
EMI SUSCEPTIBILITY AND RADIATION			
Construction indicates that signal and power return are grounded to chassis			X
External power isolated by transformer	X		
All connections through front panel	X		
FLAMMABILITY			
Sealed unit	X		
Plastic panel knobs			X
TOXICITY			
No prohibted toxics identified			
Sealed unit	X		
CONTAMINATION GENERATION			
CRT face containment may not be with plastic		X	
ATMOSPHERE			
>90% RH	X		
AMBIENT TEMPERATURES			
Operating temperature range: 0 to 55 C (32 to 131 F)	X		
EQUIPMENT COOLING			
External air flow adequate	X		
ZERO-G EFFECTS			
No gravity dependent functions	X		
OPERABILITY			
Bodily contact with knobs and handles possible			X

2.25.5 Modifications

Construction

Shatterables.

1. Replace CRT viewing cove with transparent Lexan
2. Cover inside of venting with fine-mesh screen

19-Inch Rack Mounting

1. Attach rack-mounting flanges per Figure 2.25-2.
2. Install taper-pin support assemblies to rear panel of lower unit and mating guide rails inside rack cabinet per paragraph 10.0 of Design Guidelines.

Vibration

1. Replace structural fasteners per paragraph 6.0 of Design Guidelines.
2. Conformally encapsulate all circuit boards per paragraph 5.0 of Design Guidelines.
3. Secure two P.C. cards per paragraph 11.0 of Design Guidelines.
4. Replace P.C. card guides (8 cards) per paragraph 3.0 of Design Guidelines.

Materials Usage

1. Provide 150-hour off-gas bakeout.
2. Cable and wiring replacement is not necessary because unit is totally enclosed.

Electrical

Rewire to remove signal return from chassis ground.

1. Replace 12 BNC coax connectors
2. Establish additional ground points on circuit board (assume P.C. grounds are not connected directly to chassis).

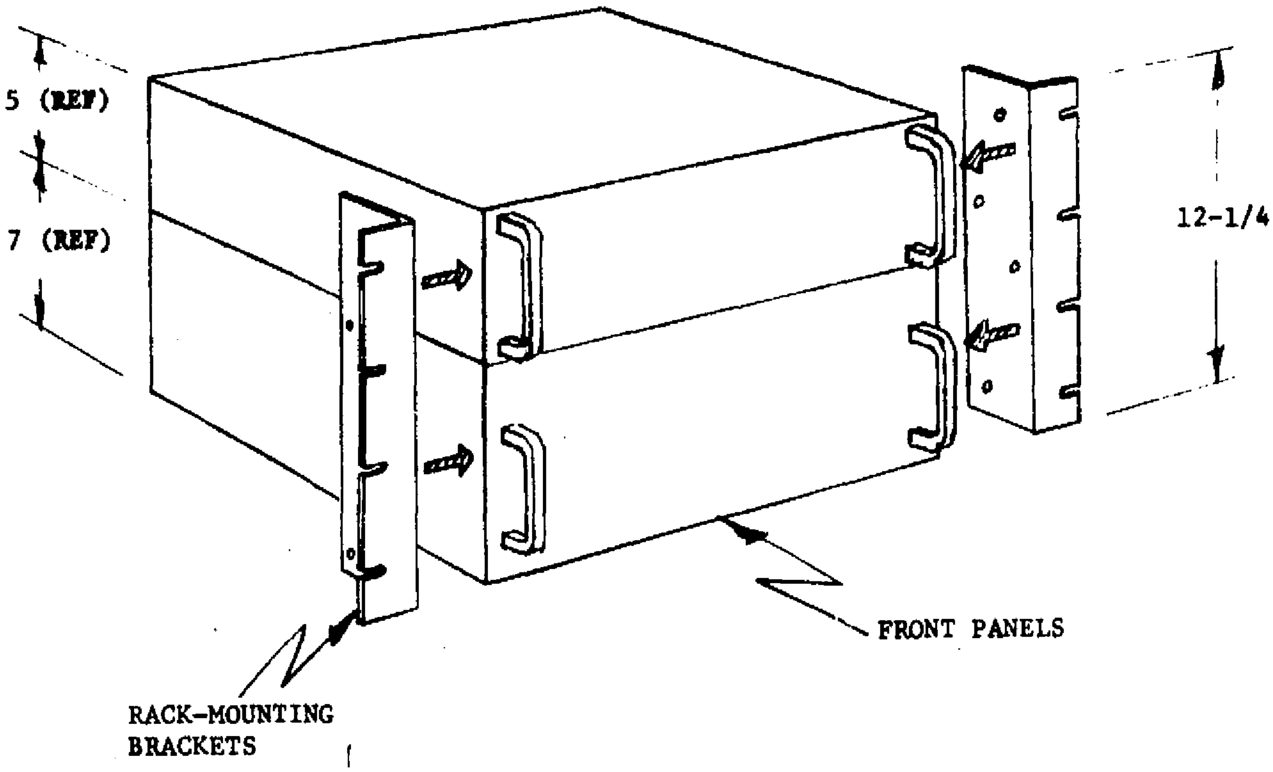

Figure 2.25-2. 19-Inch Rack Mount

2.25.6 Cost Analysis

Modification

Basic Cost		$ 8,037
Modification Cost		
Fabrication	$ 3,040	
Engineering	11,684	
Test	4,416	
Documentation	2,160	
Program Management	1,065	
Total Modification Cost		$ 22,365
Total Cost		$ 30,402

New Development

Cost	$ 452,000
Weight	35 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter Communications

2.25.7 EC006M Delta Modification Requirements Summary

1. Provide nonoperating vacuum capability (delta)
   a. Respecify and replace 30 electronics parts for vacuum
   b. Add vacuum chamber and test time
2. Provide external test capability to test items to replaceable assembly level
   a. Add one 50-pin connector to external panel
   b. Add a 50-wire test harness
   c. Add a hardmounted test signal isolation circuit PCB (20 discretes)
3. Seal the following connectors/wire junctions against moisture
   a. 15 PCB connectors (printed pin plugs)
   b. 6 internal BNC coax connectors
   c. 3 external BNC coax connectors
   d. 3 external I/O connectors (multi-pin)
   e. 1 internal harness connector

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. SSB-50-1&CA-5-1/MFS ASSEMBLY NAME Spectrum Analyzer NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	EXPD.				COST $ MAT'L	LABOR	TOTAL
		Fab. Lexan Cover	2	2.00		.20							10.00		
		Cover Venting with Mesh	AR	5.00		.50		1.00					10.00		
		Fab. Flanges	2	2.50		.25							5.00		
		Fab. Guide Pins & Reels	[illegible]	3.50	1.00	.20							22.50		
		Replace all Fasteners	165		20.00	5.00	20.00	12.00					41.25		
		Conformal Coat PCBS	8		10.00	1.00							24.00		
		Secure PCB	2	1.00	.20	.10							.70		
		Replace PCB Guides & Fab. RM	2	3.00	1.00	.30							2.50		
		150 Hour Bake						16.00					500.00		
		Replace RBNC Conn. with Insulated	12		12.00	2.00							24.00		
		Ground Lines to PCBS	8		2.00	.50							2.00		
		Test & Recalibrate	AR			16.00	24.00	8.00	8.00						
		TOTAL HOURS		18.50	46.20	26.05	44.00	37.00	8.00				641.95		

LOT SIZE FROM	TO		MAT'L	LABOR	TOTAL
		RATE			
		O.H.			
		TOTAL	641.95	2397.70	3039.65
		TOTAL			
		TOTAL			

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4. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**
5. Replace PVC as follows (delta to SEEIR mode only)

   a. 7 cables of 15 wires each in 2 main frames and one module

   b. 100 loose wire (in 6 assemblies)

6. Human factors mods as follows

   a. Add captive 1/4 turn panel fasteners (8)

   b. Add silk screen on instrument (39 controls)

2.25.8 Delta Modification Costs

Fabrication	$ 1,255	
Engineering	19,725	
Test	5,483	
Documentation	2,562	
Program management	1,451	
Total delta modification cost		$ 30,474

2.25.9 Data Sources

1. High Resolution Spectrum Analyzer Systems Model SSB-50-1. Singer Instrumentation, 1/72.

2. Panalyzer Module, Model CA-5-1 Instruction Manual No. 110-5076.

3. Main Frame, Model MF-50, Instruction Manual No. 110-5036.

4. Model RF8 Tuning Head and Model MF-8 Main Frame, Instruction Manual No. 110-5028.

5. Two-tone Audio Generator, Model TT6-3, Instruction Manual No. 110-5033.

6. Range Extending Converter, Model REC-2, Instruction Manual No. 110-5032.

2.26 Multichannel Analyzer

Manufacturer: Nuclear Data
Model Number: ND 100
Cost: $7500

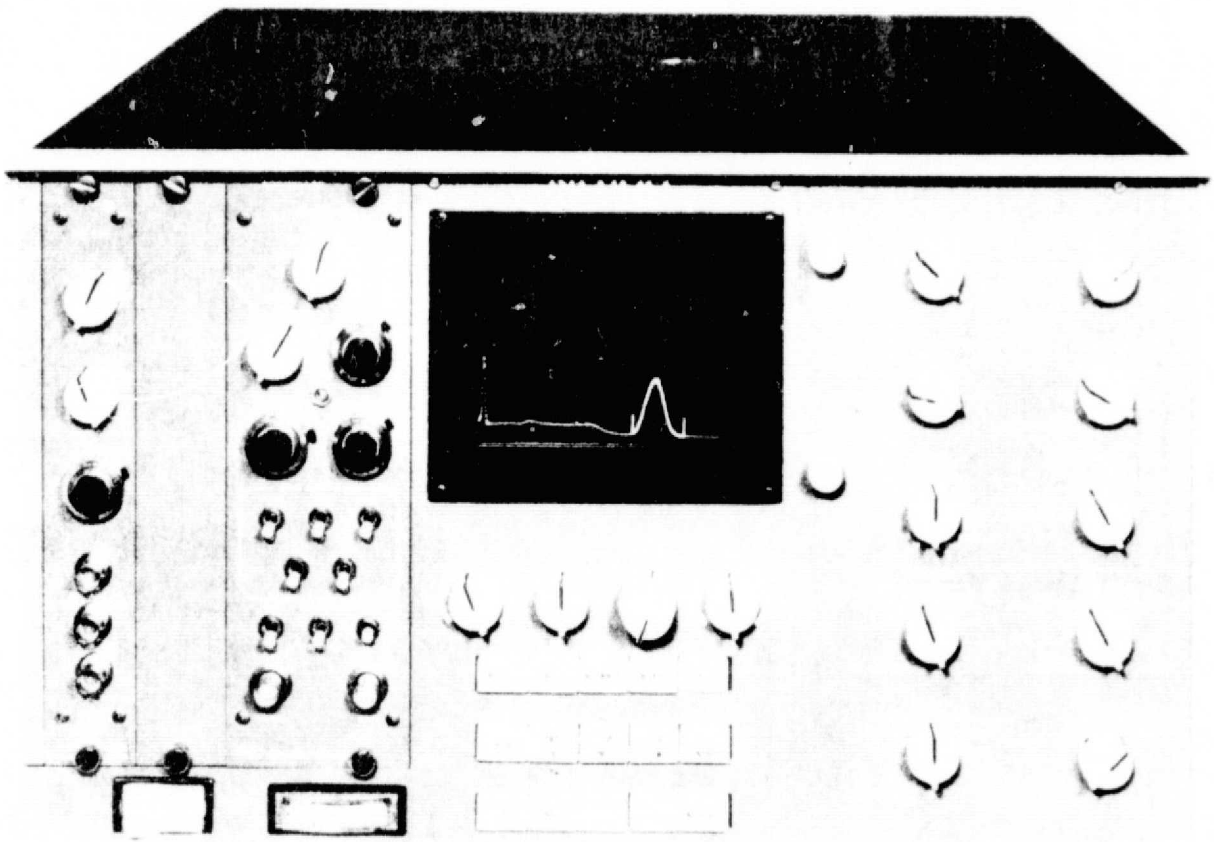

Figure 2.26-1. Nuclear Data Multichannel Analyzer

2.26.1 Description

The ND 100 Multichannel Analyzer System consists of a 19-inch rack mount or benchtop console, containing data handling control circuits, solid-state memory, display oscilloscope, input/output interfaces, ADC, power supply, and a 4-wide NIM enclosure.

The built-in NIM enclosure accepts Nuclear Data's Model ND 560 ADC analog-to-digital converter module (which is included with each system) and optional front end signal conditioning modules. Additional plug-in modules and NIM bins are available to expand the ND 100's capabilities to provide digiplex/dual parameter operation, multispectra scaling, and time of flight analysis.

2.26.2 Performance Characteristics

Data Acquisition

Data acquisition can be in three modes: PHA, MCS or LIST.

PHA

Acquisition Control	Preset live or clock time; preset total; or preset level.
Preset Time (Total) Selection	1, 10, 100, 1K, 10K, 100K, 1M or 10M seconds (counts) in multiples of 1 to 9 and infinity.

MCS

Acceptable Count Rate Range	0 to 15 MHz
Pulse Pair Resolution	60 nsec
Dead Time Between Channels	2.25 μsec
Dwell Time Selection	10, 100, 1K, 100K or 1 M sec in multiples of 1 to 9
Count Input	Pulse Amplitude: +2.4 volts to +5 volts Duration: 30 ns, minimum. Input Impedance: 75 ohms
External Sweep Trigger Input	Pulse Amplitude: +3 volts to 0 volts, with storage cycle and channel advance occurring on negative transition of pulse. Duration: 0.5 μsec, minimum. Input Impedance: 130 ohms

LIST

Storage	12-bit data words, stored sequentially
Acceptable Data Rate	100 kHz, maximum
Control	By data source

Data Display

All spectrum and alphanumeric experimental data are displayed on the built-in oscilloscope. The alphanumeric data can be displayed simultaneously with spectra or turned off.

Cathode Ray Tube Parameters. Phosphor--green, P31. Display face--flat, rectangular (6 x 10 cm, full screen). Dot size--0.3 mm at medium intensity.

Display Modes. Linear: Full-scale calibrations from 64 to 1M counts full-scale in binary increments. Six-decade logarithmic scale.

Display Rate. 100 kHz

Linear Display Resolution. 1 part in 1000

Horizontal Display Expansion. Any segment of display can be expanded by a factor of up to 5.

Horizontal (Scanmaster) Adjustment. Positions any expanded segment (as small as 20 percent of full scale) on display.

Area Selection. By means of dual (left and right) channel markers.

Alphanumeric. Internal circuitry permits alphanumeric display of nine experimental parameters (1 and 2) channel numbers of each marker, (3 and 4) content (counts) at each marker channel, (5 and 6) energy at each marker channel (optional), (7) total counts within current marker defined area, (8) current elapsed time (live or clock), and (9) current content of preset register.

Overlap. Stored data in two selected memory groups can be overlapped and normalized.

Data Input/Output

Ancillary Oscilloscope or X-Y Plotter

Horizontal Output	0 to +1 volt (internal adjustment)
Vertical Output	0 to +1 volt (internal adjustment)
Z Intensity Output	+5 volts, blank; 0 volts, normal (unblank). Internal strapping for complementary output is provided.
Plot Seek Output	Pulse Amplitude: +2.4 volts to +5 volts
Plot Complete Input	Pulse Amplitude: +2.4 volts to 5 volts; duration, 1 μsec, minimum
Input/Output Rate	10 char/sec (110 baud)

Data Storage (Memory)

Number of Channels. 1024, 2048 or 4096 plug-in; field expandable from 1K to 2K to 4K.

Count Capacity per Channel. 2^{20} to 1 (1,048,575) +4 internal flag bits.

Type. Solid state, random access, 24-bit parallel.

Cycle Time. 2.0 μsec.

NIM Enclosure and Power Supply

Module Receptacles. Four Amp type 202516-3 connectors, wired in parallel.

Power Output. +12 vdc @ 2A, -12 vdc @ 1A, $\pm$24 vdc @ 0.25A.

ND 560 ADC Module

Conversion Gain. 128, 256, 512, 1024, 2048 or 4096 channels full scale.

Digitizing Rate. 50 MHz on all conversion ranges.

ADC Conversion Time. 6 + 0.02N μsec on all conversion ranges where N is equal to the number of address advances for a given input event. The fixed dead time (6 μsec) includes initialization, pedestal rundown, delay line propagation, bad data flag check, etc.

Signal Input. Coupling: ac or dc, switch selectable
Amplitude: 0 to +8 volts, nominal
Polarity: positive monopolar or initially positive bipolar
Rise Time: 0.2 to 70 sec.
Duration: 1 μsec, minimum
Internal Delay: 1 μsec
Input Impedance: 1000 ohms

Linearity. Integral: Better than 0.075 percent over 99 percent of full scale

Differential: Less than 1.0 percent deviation from mean channel width over 99 percent of full scale

Stability. Time: Less than 0.5 channels per day at stable ambient temperature

Temperature: Less than $\pm$0.01 percent zero shift and less than $\pm$0.01 percent gain shift per 1 C from 15 to 40 C.

2.26.3 Physical Characteristics

Dimensions

19-in. wide x 10.25-in. high x 23.5-in. deep
(48.3 x 26 x 59.6 cm)

Weight

60 pounds net with ND560 ADC (27.2 kg)

2.26.4 Suitability Analysis

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. Compact unit with NIM modules integrated into its housing. Wire connections are wire-wrap instead of solder in fixed memory section. Circuit boards are installed behind the integral CRT. Unit can be obtained in either rack or bench mount.			
MATERIALS			
PVC insulation Glass Aluminum Plastic knobs			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Edge mounted power supply heat sink board requires support			X
Ribbon cables and conventional cabling from NIM modules require tie down			X
End mounted transformer requires support			X
CRT "stand" requires support at top			X
Support 8 x 10" circuit board with large capacitors and heat sink from oil canning			X
Cushion rear circuit boards from buzz			X
Wire wrap/IC circuit boards require additional support			X
Capacitors in high voltage power supply section require support			X
ELECTRICAL POWER			
Power requirements: 115/230 V ac, 50/60 Hz, 200 W	X		
DATA MANAGEMENT COMPATIBILITY			
0 - 5 volt TTL <12K output	X		
EMI SUSCEPTIBILITY AND RADIATION			
Metal case and 5 volt logic reduces EMI radiation potential		X	

	Disposition		
	Accept	Verify	Unaccept
NOISE GENERATION			
2 fans are noisy ∿ 65 to 70 db			X
FLAMMABILITY			
Plastic knobs			X
PVC insulation			X
TOXICITY			
No prohibited toxics or large quantities of potential generators identified	X		
CONTAMINATION GENERATION			
CRT metal shield has openings at high voltage input and at rear of enclsoure that could allow glass fragments to escape			X
Thin plastic grid face shields CRT in front to enclose glass in event of breakage; prevent frontal breakage			X
ATMOSPHERE			
Compatible with Spacelab	X		
AMBIENT TEMPERATURES			
Operating temperature range: 0-45 C (32-113 F)	X		
EQUIPMENT COOLING			
Forced air cooling provided by integral fan	X		
ZERO-G EFFECTS			
No gravity dependent functions	X		
OPERABILITY			
Requires protrusion protection			X
Remove connector extension from internal stowage			X

2.26.5 Modifications

Construction

Shatterables. Due to glass components (CRT), cover inside of venting with fine-mesh screen.

9G Mounting. Attach 19-inch rack-mounting flanges supplied with unit. Install taper-pin support assemblies to lower rear panel of unit and mating guide rails inside rack cabinet per paragraph 10.0 of Design Guidelines.

Protrusion Protection. Install protection rails on rack cabinet per paragraph 12.0 of Design Guidelines.

Shock and Vibration.

1. Modify transformer/heat sink assembly per Figure 2.26-2.
2. Secure rear-chassis power transformer per Figure 2.26-3.
3. Secure CRT tube assembly per Figure 2.26-4.
4. Modify 8 x 10 programming circuit boards to prevent "oil-canning". Attach large components with clips per paragraph 4.0 of Design Guidelines. Install tie-down clamps per Figure 2.26-5.
5. Replace all structural fasteners per paragraph 6.0 of Design Guidelines.
6. Increase number of fasteners in top cover.

Acoustics. Replace cooling fan unit with one of a suitable acoustic level.

Materials Usage

1. Conformal coat circuit boards with suitable flame-retardant conformal coating.
2. Provide 150-hour off-gas bakeout.
3. Remove existing wiring (except for wire-wrap interconnect on PC boards) and replace with suitably-insulated wires. Number of wires: approximately 375.

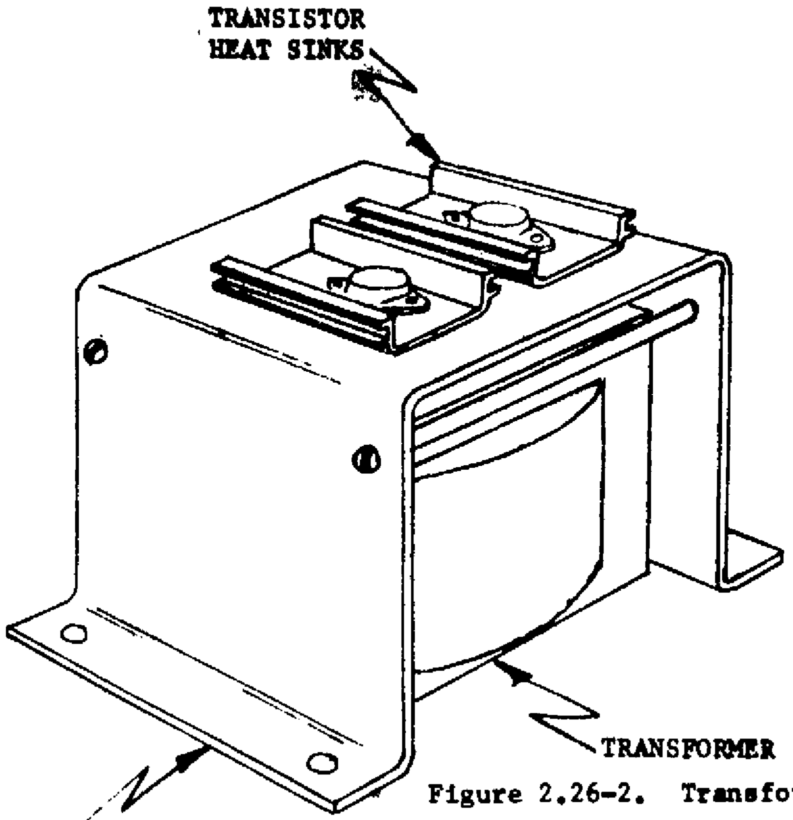

Figure 2.26-2. Transformer/Heat Sink Assembly

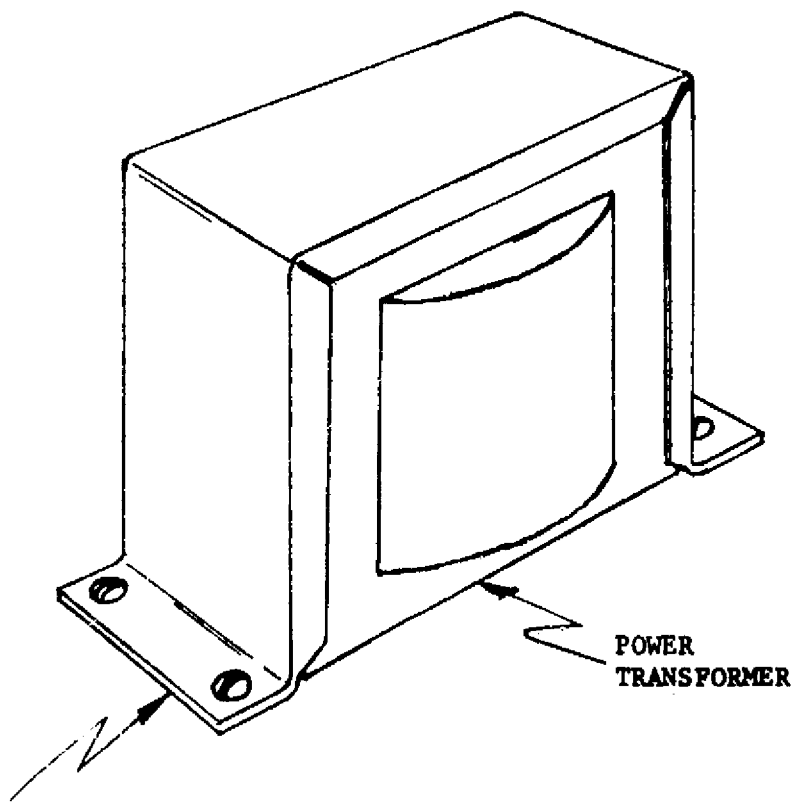

Figure 2.26-3. Power Transformer Securing

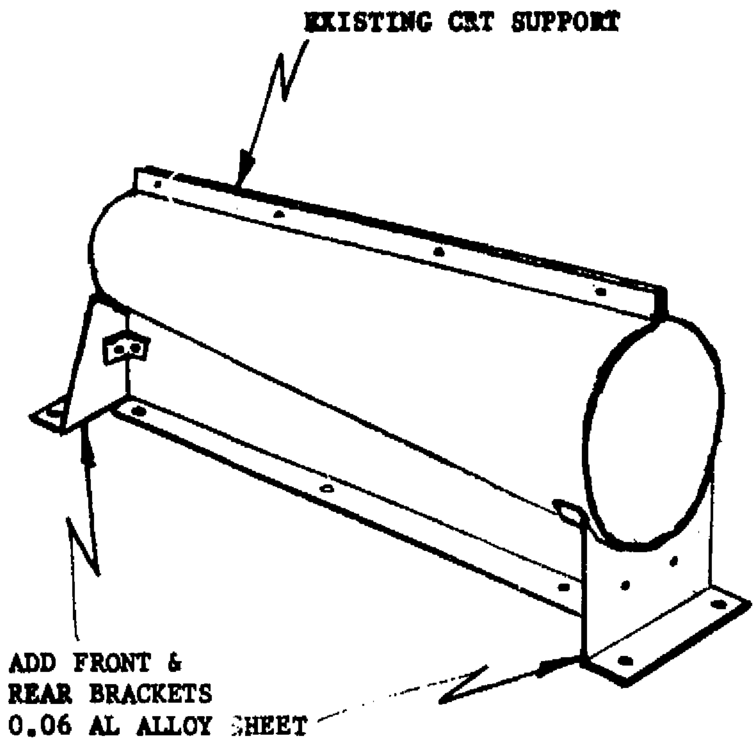

Figure 2.26-4. CRT Mounting

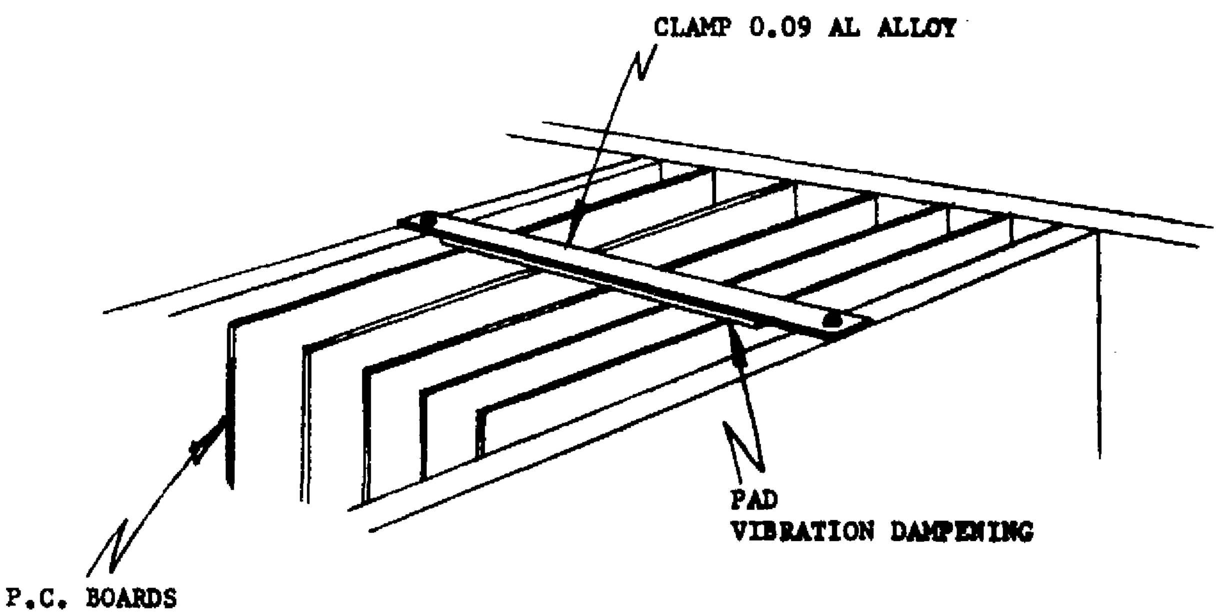

Figure 2.26-5. P.C. Card Securing

2.26.6 Cost Analysis

Modification

Basic Cost		$ 8,611
Modification Cost		
Fabrication	$ 5,665	
Engineering	15,070	
Test	4,416	
Documentation	2,160	
Program Management	1,366	
Total Modification Cost		$ 28,677
Total Cost		$ 37,288

New Development

Cost	$ 581,000
Weight	45 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter Avionics

2.26.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal range capability
   a. Respecify and replace 200 electronics parts (40 IC's) for vacuum/thermal range
   b. Add test chambers and test time for qual and acceptance
   c. Replace lubricants in 2 fan motors
2. Provide connector interface to externally test items to replaceable assembly level
   a. Add two 50-pin external interface panel connectors
   b. Add a 100-wire test harness to 13 assemblies
   c. Add a hardmounted test signal isolation PCB (40 discretes)
3. Seal the following connectors/wire junctions against moisture
   a. 8 external interface BNC connectors
   b. 8 memory board connectors for ribbon cable (not printed pins)
   c. 7 PCB connectors (printed pins)
   d. 2 NIM module standard connectors (internal to ND 100)

32-23-07.1

MANUFACTURING :OST ESTIMATE

ASSEMBLY NO. Nuclear Data 100 ASSEMBLY NAME Multichannel Analyzer NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.		COST $ MAT'L	LABOR	TOTAL
		Cover Inside of Venting	X	8 00		1 00				20 00		
		with Fine Mesh										
		Fab. & Attach Taper Pin		3 50	1 00	20				22 50		
		Support Assy & Rack Flanges			50							
		Fab. Protection Rails	2	2 00		20				10 00		
		Modify Transformers	1	4 50	1 00	50	2 00			3 50		
		Fab. Support & Heatsinks										
		Secure Rear Chassis Trans	1	3 50	1 00	35				3 00		
		Fab. Bracket										
		Fab. CRT Mount Bracket	1	4 00	1 25	40				3 00		
		Modify PCB w/Standoffs	5	5 00	2 00	50				5 00		
		Install Component Clips	40				4 00			10 00		
		Fab. PCB Holddown	1	1 00	15	20				1 00		
		Replace all Hardware per Est.			20 00	10 00	40 80	[illegible]0 00		33 75		
		135 Pieces										
		Increase # of Fasteners into		2 00	50	30				2 50		
		Est. 10										
		Replace Cooling Fan		4 00	1 50	1 00	2 00	1 00		125 00		
		Conformal Coat PCB's	5		7 50	1 00				15 00		
		150 Hour Bake Out						16 00		500 00		
		Replace all Wiring	375		37 50	6 00		20 00		40 00		
		Support of Above Modifications				8 00		20 00	20 00			
		Test & Recalibrate				10 00	40 00					
		TOTAL HOURS		37 50	73 90	39 65	38 00	90 00	20 00	794 25		

Beckman INSTRUMENTS, INC.	LOT SIZE FROM	TO	RATE	MAT'L	LABOR	TOTAL
			O.H.			
			TOTAL	794 25	4871 19	5665 44
			TOTAL			
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4. Replace PVC as follows (delta to SEEIR mods only) one
   a. 100 loose wires
5. Human factor mods as follows
   a. Add captive 1/4 turn panel fasteners (4 places)
   b. Add silkscreened operating instructions to panel (32 controls)
6. Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.

2.26.8 Delta Modification Costs

Fabrication	$ 1,447	
Engineering	31,206	
Test	5,741	
Documentation	2,562	
Program Management	2,048	
Total delta modification cost		$ 43,024

2.26.9 Data Sources

1. Visual examination
2. PS 1002 5.0 ND 100 Multichannel Analyzer, Nuclear Data Inc., January 1974

2.27 COMMERCIAL TAPE RECORDER

Manufacturer: Honeywell, Inc.
Model Number: 5600
Cost: $9,730

Figure 2.27-1. Honeywell Tape Recorder (Model 5600)

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2.27.1 Description

The Honeywell Model 5600 Magnetic Tape System is a full 14-channel instrumentation grade recorder. Extensive use of aerospace technology and electronics enable laboratory performance in a portable package weighing approximately 70 lb (31.8 kg). The basic recorder accommodates data cards for any combination of record/reproduce channels totaling sixteen. An auxiliary data electronics housing is available for expansion to a total of 32 data cards.

Built-in features permit conversion of tape width, power source, and recording technique to meet a variety of special requirements at remote locations. Plug-in equalizers and center frequency filters provide configuration flexibility. Two equalizers of center frequency filters are electrically switched with the rotary tape speed selector; in addition, the capability to use thin base tape, 7200 ft on 10-1/2 inch reels, provides recording time equal to that of larger systems.

The Model 5600 Portable Magnetic Tape Systems are capable of recording/reproducing up to 14 channels of data at seven servo controlled tape speeds. Standard magnetic heads are IRIG compatible; however, other configurations are available. The optional methods of data handling include: direct (analog), FM (±40-percent deviation), and serial digital. Voice channel is also available. Each direct record, FM record, or digital write card is capable of recording one channel of data at any of the seven tape speeds. Each direct reproduce. FM reproduce. or digital read card can be equipped with two plug-in modules (amplitude equalizers for direct, center frequency/bandwidth filters for FM, or gain resistors for digital) to process one channel of data at any two of the seven tape speeds.

2.27.2 Performance Characteristics

Tape Transport

Basic Configurations	1/4, 1/2 or 1 in. easily field convertible between basic configurations
Tape Speeds	60, 30, 15, 7-1/2, 3-3/4, 1-7/8 and 15/16 ips. Bidirectional and electrically selected by rotary switch. Continuously variable speed with external oscillator.

Hubs, Reels and Tape Width

Reel Outside Diameter		Reel Hole Size			Tape Width	
in.	(cm)	in.	(cm)		in.	(cm)
5	(12.7)	5/16	(.79)	NAB	1/4	(.64)
7	(17.8)	5/16	(.79)	NAB	1/4	(.64)
8		3	(7.62)	NAB	1/4,1/2,1	(.64,1.28,2.56)
10-1/2	(26.7)	3	(7.62)	NAB	1/4,1/2,1	(.64,1.28,2.56)
10-1/2	(26.7)	5/16	(.79)	NAB	1/4	(.64)

Universal adapter accepts all of above combinations. Spacer required for 1/4-inch reels with 3-inch hub. Audio reel knobs are available.

Start Time	3.5 sec max at 60 ips
Stop Time	3.0 sec max at 60 ips
Fast Mode Speed	150 ips
Static Skew	Adjustable record and reproduce head azimuth to reduce static skew to less than ±1 μsec between outside tracks on a single 1-inch head stack at 60 ips.
ITDE (Dynamic Skew)	±1 μsec measured per IRIG 106-69 between outside tracks of a single 1-inch head stack at 60 ips. Proportionately higher at lower tape speeds.
Flutter	Measured per IRIG-106-69; servoed from capstan motor tachometer in record and reproduce.

Tape Speed (ips)	Bandwidth (Hz)	Cumulative Flutter % P-P (2 Sigma)
60	0.2 - 10,000	0.25
30	0.2 - 5,000	0.30
15	0.2 - 2,500	0.35
7-1/2	0.2 - 1,250	0.40
3-3/4	0.2 - 625	0.40
1-7/8	0.2 - 312	0.40
15/16	0.2 - 156	0.45

Remote Indicators

End of tape	+5 vdc at 40 ma max
Low tape sensor (optional)	+5 vdc at 40 ma max

Tape Drive System

Capstan System	Tri-Capstan; bi-directional and equivalent to closed loop in high frequency flutter suppression. DC drive motor is directly coupled to center capstan.
Capstan Servo	Phase lock from tape or motor tachometer. Servo system will generate standard or 2X standard IRIG constant amplitude servo frequencies. The servo system will remove a static recorded speed error of +50% and -30% at any speed from 1-7/3 ips to 30 ips; +50% and -20% at 60 ips; +35% and -25% at 15/16 ips.

Speed Accuracy (Over operating temperature range)

Capstan Rotational Accuracy	0.1% when servo is operating from motor tachometer
Tape Speed Accuracy	Within 0.15% of selected speed when servo is operating from motor tachometer; within 0.05% of recorded reference when operating from tape.

Magnetic Heads

Five Standard Configurations Available

Tape Width in.	(cm)	No. of Tracks	Format	Track Width in.	(cm)	Track Spacing (C-C)	No. of Edge Tracks
1/4	.64	4		0.040	(0.1)	0.068	0
1/4	.64	7	2X IRIG	0.025	(0.064)	0.035	0
1/2	1.28	7	IRIG	0.050	(0.128)	0.070	1
1/2	1.28	14	2X IRIG	0.025	(0.064)	0.035	0
1	2.56	14	IRIG	0.050	(0.128)	0.070	2

Direct Record/Reproduce

Dynamic Characteristics. Based on standard IRIG head configurations without an FM channel on an adjacent track, and with recommended iron oxide tapes. Capable of operation with high-energy tapes.

Tape Speed (ips)	Bandwidth (Hz ± 3 dB)	RMS Signal/RMS Noise (dB filtered)*	(dB unfiltered)
60	300 - 300,000	40	30
30	150 - 150,000	39	30
15	100 - 75,000	38	30
7-1/2	50 - 37,500	30	28
3-3/4	50 - 18,750	30	28
1-7/8	50 - 9,300	29	26
15/16	50 - 4,700	29	26

*NOTE: Measured at the output of a bandpass filter having 18 dB/octave attenuation beyond bandwidth limits.

Harmonic Distortion	Normal record level set for 1% third harmonic distorition of a 1 kHz signal recorded at 60 ips.
Input Level	0.3 to 3.0V rms
Input Impedance	100K ohms resistive paralleled by 100 pF, unbalanced to ground.
Output Level	1.0V rms to 10K ohms nominal
Output Impedance	Less than 100 ohms

FM Record/Reproduce (±40-Percent Deviation)

Dynamic Characteristics

Bandwidth (within 1 DB) and RMS signal-to-noise ratio.

	Low Band			Intermediate Band			Wideband Group I		
Tape Speed (ips)	CF (kHz)	BW (kHz)	SNR (dB)	CF (kHz)	BW (kHz)	SNR (dB)	CF (kHz)	BW (kHz)	SNR (dB)
60	54	10	51	108	20	51	216	40	49
30	27	5	49	54	10	49	108	20	48
15	13.5	2.5	49	27	5	49	54	10	48
7½	6.75	1.25	48	13.5	2.5	48	27	5	48
3¾	3.37	0.625	47	6.75	1.25	47	13.5	2.5	47
1⅞	1.68	0.312	47	3.37	0.625	46	6.75	1.25	45
15/16	0.84	0.156	45	1.68	0.312	45	3.37	0.625	41

Linearity	±0.3% of full scale deviation from best straight line through zero.
Drift	±0.5% of full scale deviation for 8 hr at any temperature between 0 and 50 C; ±0.1%/deg C maximum, over a range of 0 to 50 C after 15-min. warmup.
Distortion	1% maximum of any frequency within the passband of any filter from 40 to 0.312 kHz; 1.3% with 0.156 kHz.
Input Impedance	20K ohms minimum in parallel with 100 pF, unbalanced.
Output Level	1.0V rms, adjustable, ±20% into 600 ohms.
Output Impedance	100 ohms maximum.

Serial Digital Record/Reproduce

Three write/read modes accommodated by pin or component change

Format:

Input	Tape	Output
NRZ level	NRZ level	NRZ level
NRZ mark	NRZ mark	NRZ mark
Pulse	NRZ mark	Pulse

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Density	600 bpi maximum
Input Level	
First level	±0.5 volts
Second level	+4 to +13 volts
Input Rise and Fall Times	
NRZ mark or level	Must be less than 10 sec.
Pulse	Must be less than 1 sec.
Input Impedance	Nominal 20K ohms paralleled by 100 pF maximum, unbalanced to ground
Output Impedance	Less than 100 ohms
Output Level	
NRZ first level	±0.5 volts
NRZ second level	+5.5 ± 1 volt
Pulse	+5.5 ± 1 volt
Output Rise and Fall Times	Less than 1 sec when terminated in 1000 ohms through 20 ft of 4G58U cable

2.27.3 Physical Characteristics

Size

Portable configuration:	23 x 13-1/2 x 9-3/4 in. (58.5 x 34.3 x 24.8 cm)
Vertical Rack Mount:	22-3/4 in. (57.8 cm) panel space in 19-in. (48.3 cm) rack
Horizontal Rack Mount:	15-3/4 in. (40 cm) panel space in 19-in. (48.3 cm) rack. Edges of deck overhang vertical frame of rack, width is 22 in. (55.9 cm)

Weight

70 lb (31.8 kg) for 7 channel/record/reproduce configuration, excluding magnetic tape

2.27.4 Suitability Analysis

Disposition		
Accept	Verify	Unaccept

CONSTRUCTION. The item is a portable tape recorder that can be obtained in rack-mounted configuration. Inputs would be at top of unit when rack mounted. Short circuit boards are mounted vertically beneath tape reels and capstan drives. See Figure 2.27-2. The inner chassis supports the circuit boards; capstan and tape construction is heavy and rigid. The case has air holes in the side, 3/16 in. x 1 in. (0.48 x 2.54 cm) to allow ventilation.

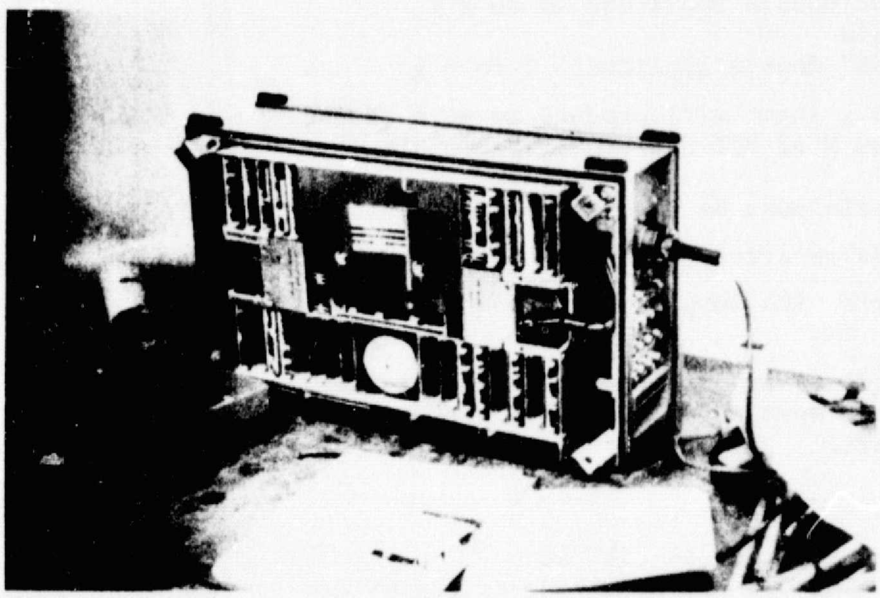

Figure 2.27-2. Interior Circuit Board Arrangement

MATERIALS

- PVC wire insulation
- Mylar tape
- Aluminum
- Typical electronic components
- Fiberglass circuit boards

SHOCK, VIBRATION, ACCELERATION AND ACOUSTIC ENVIRONMENT. Mount accommodates portable version of Model 5600 recorder. Quick attach/release latches. Controls, input/output connections and adjustments are easily accessible.

Shock. No damage will occur from a shock applied in any axis of 15 g's, 11 msec duration, half sine (MIL-STD-810B, Method 516, Procedure I).

Crash Safety. 30 g's, 11 msec (MIL-STD-810B, Method 516, Procedure III).

Vibration. Peak-to-peak flutter will not exceed 1.5 times the specified value with the following inputs applied in any axis.

5 to 22 Hz: 0.080" double amplitude .1 to 2 g
22 to 33 Hz: 2.0 g's
33 to 56 Hz: 0.036" double amplitude 2 to 6 g

From 56 to 100 Hz, a 5 g input will produce no more than 2% fultter (modified curve M of MIL-STD-810B, Figure 514.1).

	Disposition: Accept	Verify	Unaccept
Large tape reels must be removed during boost	X		
Circuit boards relatively small	X		
One large board with large center mass requires ruggedizing.			X
Similar recorders have been flown. One has been mounted on road work tractor for two years, indicating good ruggedness.			

ELECTRICAL POWER

Input Supply: 107-127/214-254V ac
48-420 Hz, 11-15V dc or 22-30V dc

Power Consumption: 275W for 7 channel record/reproduce

DATA MANAGEMENT CAPABILITY

	Disposition: Accept	Verify	Unaccept
Good shielding design	X		
Power supply returns are grounded to chassis			X
Power supply is enclosed in metal; heavy external case	X		
Signal shields carried through connectors	X		

Item	Disposition: Accept	Disposition: Verify	Disposition: Unaccept
NOISE GENERATION			
Fans noise estimated to be approx. 70 dB			X
Fast rewind/forward causes air noise; noise waived as good indication that tape is operating at fast rate.	X		
FLAMMABILITY			
Mylar tape		X	
PVC insulation			X
Plastic tape deck corners			X
TOXICITY			
No prohibited toxins or large quantities of potential generators identified	X		
CONTAMINATION GENERATION			
No shatterables	X		
CONTAMINATION SUSCEPTIBILITY			
Dust on tape head can affect performance		X	
RELIABILITY			
Minimum magnetic head life (1500 hours)	X		
Unit MTBF, 2300 hours	X		
ATMOSPHERE			
Altitude — Operating: to 15,000 ft (4.6 km)	X		
Altitude — Storage: to 50,000 ft (15.1 km)			
Humidity: 5.95% non-condensing			

	Disposition: Accept	Disposition: Verify	Disposition: Unaccept
AMBIENT TEMPERATURES			
Temperature Operating: 0 to +50 C Storage: -40 to +70 C	X		
EQUIPMENT COOLING			
Unit has two vanaxial fans providing forced-air convection.	X		
ZERO-G EFFECTS			
Not gravity sensitive.	X		
OPERABILITY			
Edge and protrusions require guards.			X

2.27.5 Modifications

Construction

9-G Mounting/Integrity. The recorder is designed for rough handling. All cables will be retained with cable clamps and all bulkhead grommets will be replaced with nylon grommets. It is estimated 25 clamps and 5 grommets will be required. Conformally coat printed circuit board--estimate 25 boards.

Protrusions and Edges Safety. Access door on front of recorder to be redesigned to conform to the .5R on all edges. See Figure 2.27-3.

Shock, Vibration, Acceleration, Acoustics Resistance. Add machined aluminum support to each motor. Replace all fasteners with CRES Nylock--estimate 300 fasteners.

Depressurization Hazard Suppression. Unit is adequately vented. Place stainless steel screens over perforated side panels.

EMI Generation Suppression. Unit EMI generation suppression is adequate. All inductive devices have suppressors installed and high current relay contacts are bypassed. All control panel switches operate on low logic level currents ($\leq$ 2 ma at 5 volts)

EMI Susceptibility Protection. Unit does not have an input ac line filter. It is suggested that a good dual coaxial RFI line filter be placed on the incoming ac line. Suggested filter is CORCOM Model 5R3 ($11.00). There appears to be sufficient space to mount filter behind input-output connector panel. See Figure 2.27-4.

Materials Usage

Concentrations of Flammable/Unidentified Materials. Wiring will be changed using TFE-insulated wire. Mylar tape requires stronger cover to seal unit. Replace knobs (2) with metal. See Figure 2.27-5. Plastic pushbuttons (6) to be replaced with buttons made from polyimide. See Figure 2.27-6.

Non-Prevalent Commercial Materials. Magnetic tape will be replaced with an approved recording tape. Steel brackets (12 estimated) to be removed. Strip off cadmium plate and nickel plate.

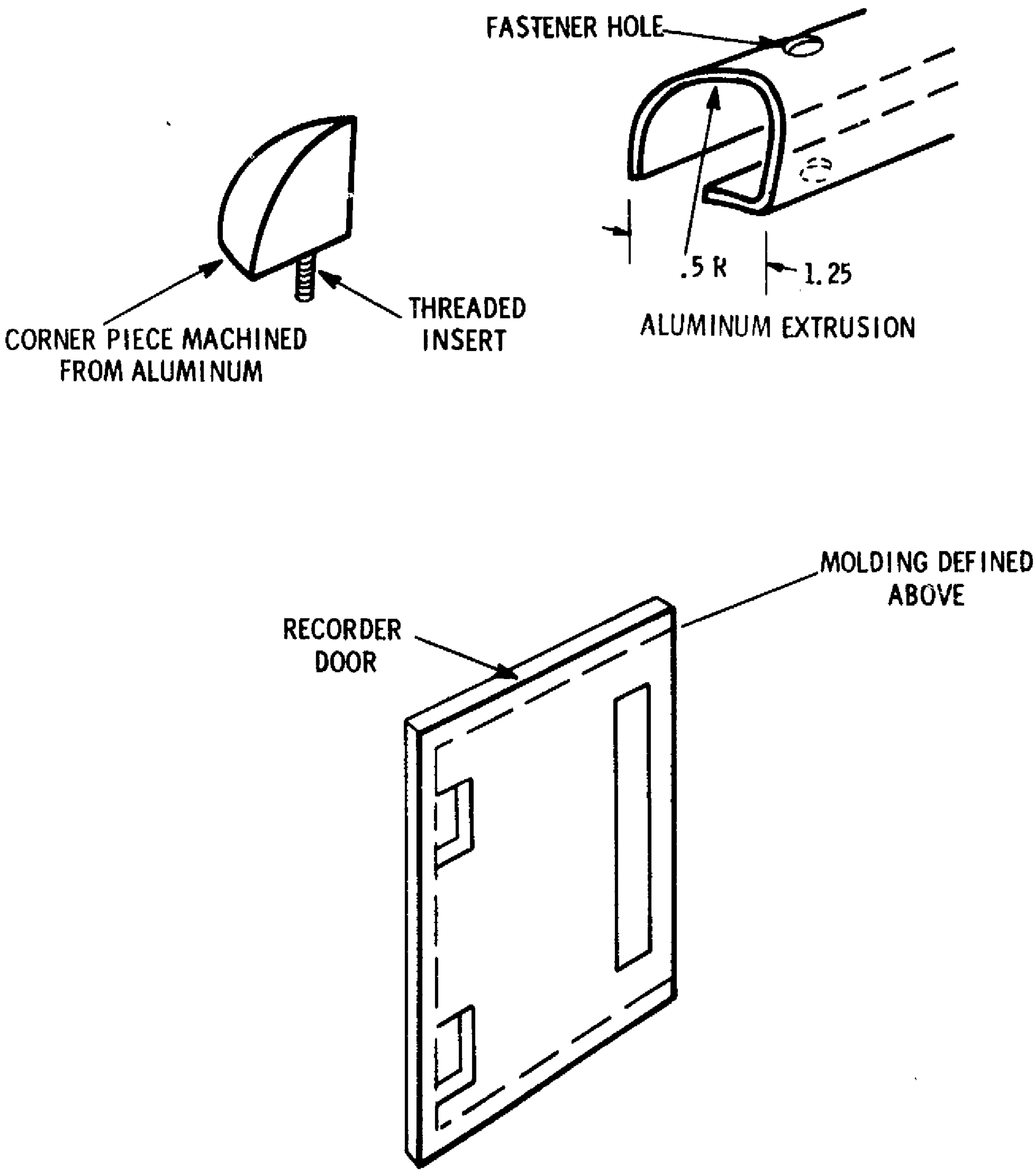

Figure 2.27-3. Protrusion Protection

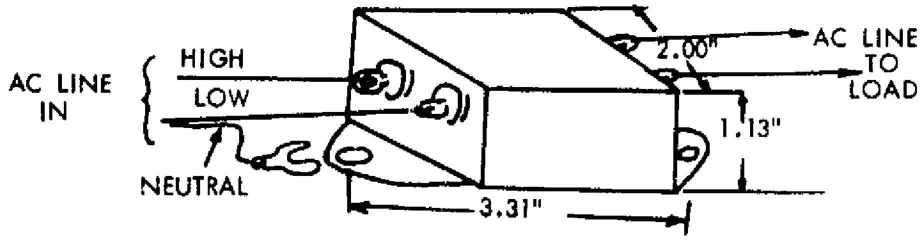

Figure 2.27-4. EMI Susceptibility Protection

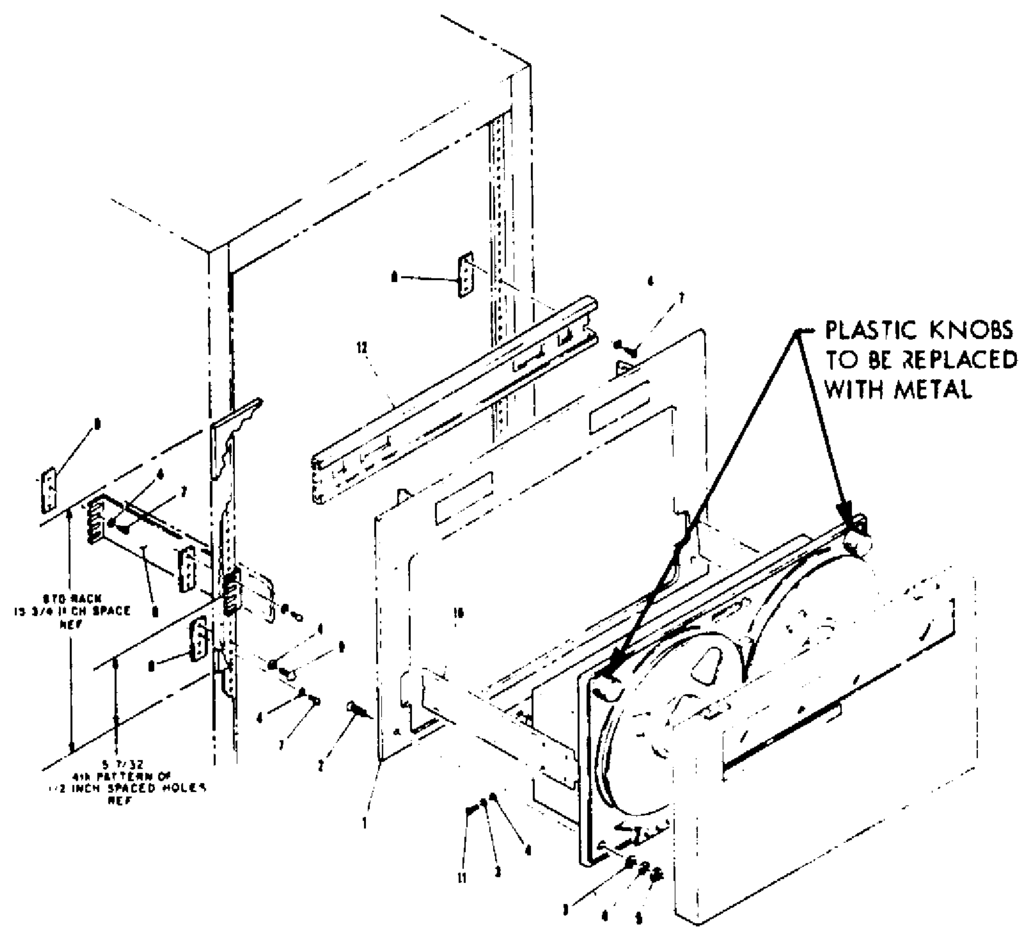

Figure 2.27-5. Plastic Knob Replacement

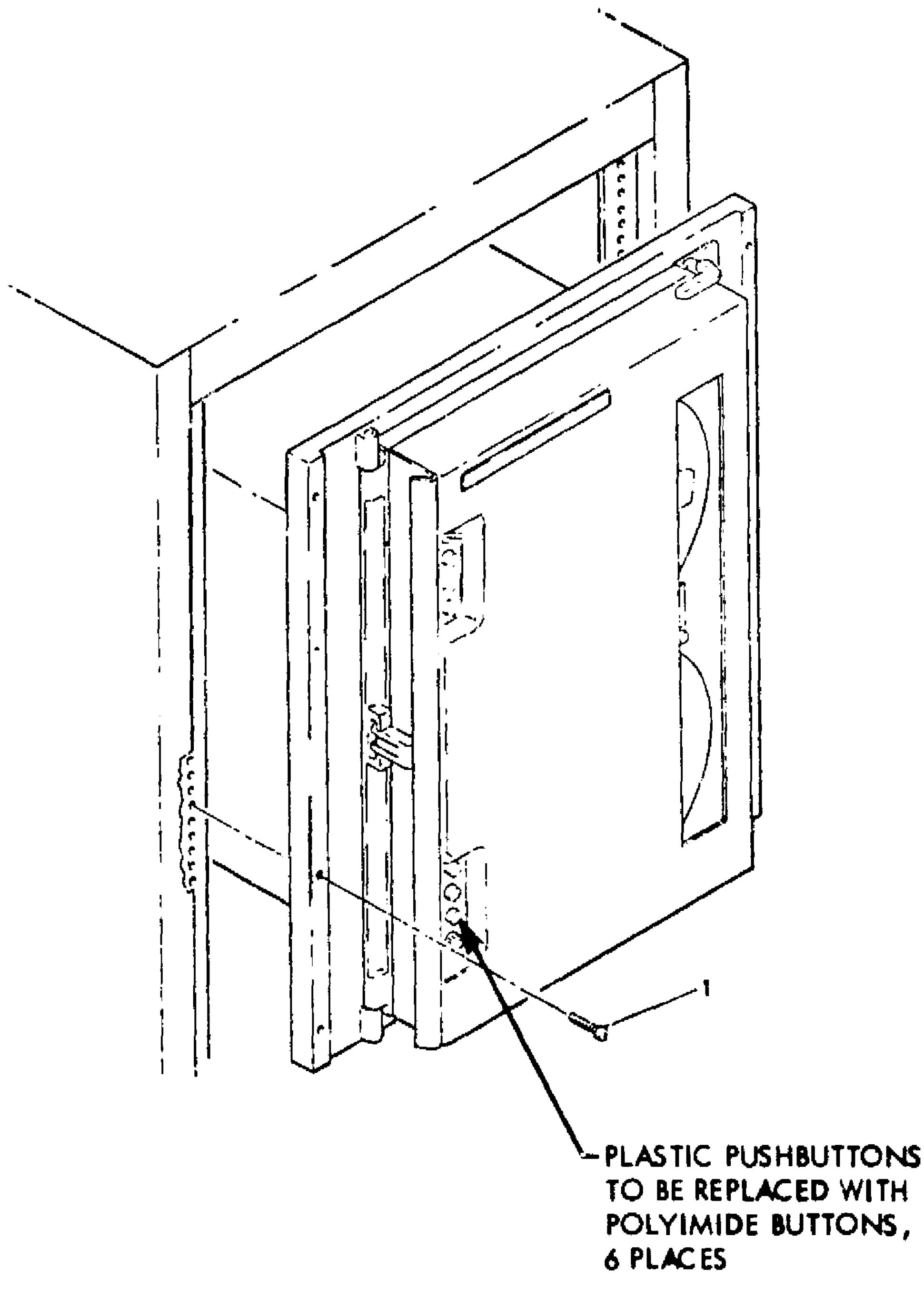

Figure 2.27-6. Plastic Pushbutton Replacement

2.27.6 Cost Analysis

Modification

Basic Cost		$ 11,171
Modification Cost		
Fabrication	$ 14,620	
Engineering	15,548	
Test	4,416	
Documentation	2,160	
Program Management	1,616	
Total Modification Cost		$ 38,360
Total Cost		$ 49,531

New Development

Cost	$ 200,000
Weight	80 pounds
Complexity	
State-of-the-Art Factor	
Data Source	Ampex Tape Recorder

2.27.7 EC006M Delta Modification Requirements Summary

1. Provide for non-operating vacuum capability

   a. Provide delta vacuum test chamber capability and test time (from current 1.6 psia) for qual and acceptance

   b. Replace lubricants in 3 capstan drive motors and roller-actuator units plus 2 fan motors

   c. Respecify and replace 100 electronic parts for vacuum

2. Provide connector interface for all item level testing

   a. Add an external interface test connector (50 pins)

   b. Add a 50-wire test harness

   c. Patch wire 25 PCB's for 50 test signals to spare PCB connector pins

   d. Add a hardmounted signal isolation circuit board (20 discretes)

3. Seal the following connectors against moisture

   a. 36 coax-type input/output

   b. Four terminal strips

   c. 25 PCB-to-master interconnect board (printed pins on PCB's)

MANUFACTURING :OST ESTIMATE

ASSEMBLY NO. Model 5600 ASSEMBLY NAME Tape Recorder - Honeywell NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	FAB	ASS'Y	INSP.	TEST	M.E.	EXPD	MFG TECH	MAT'L	LABOR	TOTAL
		Secure Cables w/Clamps	25		1.25	.20		1.00			5.00		
		Replace Bulkhead Grommets	5		1.00	.15		.50			2.50		
		COnformal Coat PCB's	25		31.25	5.20		2.30			75.00		
		Fab. & Install Dress Strip	4	4.00	2.00	.50					12.00		
		Fab. & Install Powers	4	4.00	1.35	.25					6.00		
		Motor Support	2	8.00	2.00	1.00		2.00			20.00		
		Replace all Fasteners w/SS	300		45.00	30.00	60.00	60.00			75.00		
		Cover Side Panels w/Screen	2	2.00		.20					3.00		
		Mount Line Filter	1	1.00		.15	1.00				11.00		
		Over Spray Outside Surfaces	AR			1.00					85.00		
		Rewire w/TFE Aproximately -	400		40.00	20.00	60.00	60.00			50.00		
		Fab. Cover		3.00		.45					7.50		
		Replace Knobs w/Metal	2	2.00	.50	.20					4.00		
		Fab. Buttons from Vespel	6	6.00	1.00	.60					100.00		
		Strip & Replate Brackets	12		8.00			4.00			120.00		
		Procure Fan Assy from Honey-			2.00			1.00			125.00		
		well-Adapt Wiring for series									2.00		
		operation											
		Other Support Required				10.00		30.00	20.00				
		Test & Recalibrate & Certify				20.00	80.00	40.00					
		150 Hour Bake Out						16.00			500.00		
		Complete Disassembly			40.00			40.00		40.00			
		Reassembly			40.00	10.00		40.00		40.00			
		TOTAL HOURS		30.00	225.35	99.70	201.00	296.50	20.00	80.00	1203.00		
		LOT SIZE FROM / TO	RATE										
			O.H.										
			TOTAL								1203.00	13417.00	14620.00
			TOTAL										
			TOTAL										

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SD 74-SA-0047-3

Space Division
Rockwell International

   d. Four molded P-J connector sets
   e. 3 interface shell connectors

4. Replace PVC as follows (delta to SEEIR mods)
   a. 50 loose wires not in harnesses

5. Human factors mods
   a. Add captive 1/4 turn panel mount fasteners (6 places)
   b. Add silkscreen operating instructions on panel face (assume 10 controls)

6. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

2.27.8 Delta Modification Costs

Fabrication	$ 1,763	
Engineering	28,244	
Test	5,502	
Documentation	2,562	
Program Management	1,903	
Total delta modification cost		$ 39,974

2.27.9 Data Sources

1. Visual examination
2. Model 5600 Recorder/Reproducer Proposal Makeup Data
3. Technical Manual 16778452-001. Model 5600C Portable Tape Recorder/Reproducer, Honeywell, January 1974
4. Test Instruments Catalog, Honeywell, 1974

2.28 AIRBORNE TAPE RECORDER

Manufacturer: Ampex

Model Number: AR-700

Cost: $30,500

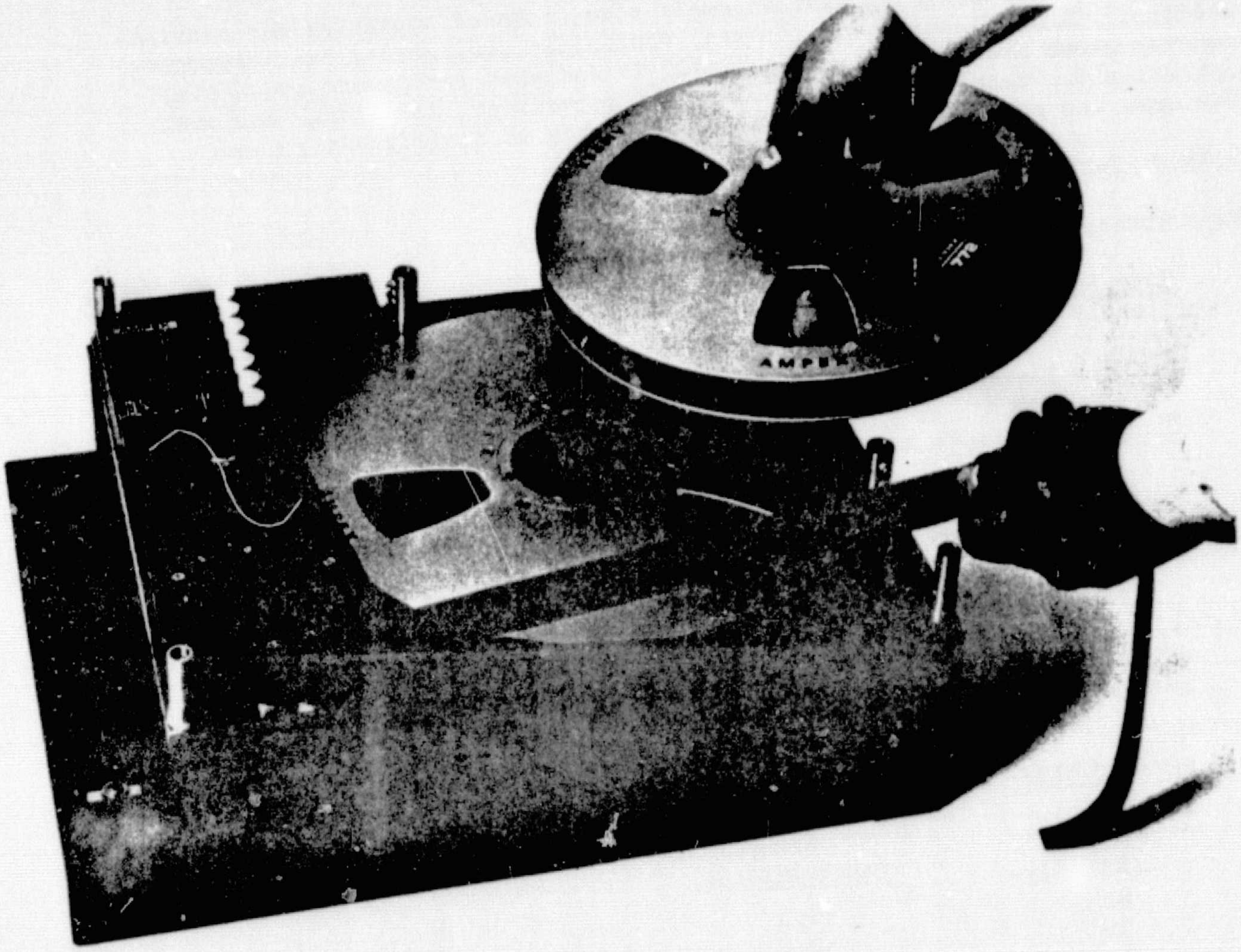

Figure 2.28-1. Ampex Tape Recorder - Model AR-700

2.28.1 Description

The AR-700 is a compact intermediate or wideband multi-channel recorder designed for airborne and other stringent environments. It is ruggedly constructed, uses servo-controlled time base correction and may be electrically switched over a range of six speeds. Up to seven channels of record electronics are provided on machines using 1/2-in. (1.28 cm) tape on 10-1/2 in. (26.7 cm) or 12-1/2 in. (31.8 cm) reels, or up to 14 channels on machines equipped for 1 in. (2.54 cm) tape.

The system design emphasizes small size, ease of operation and serviceability. Closed loop capstan design, concentric reels and a fast response capstan servo are featured. The AR-700 is designed for remote sequential operation for those needing uninterrupted recording. Additional optional features and custom modifications are available to satisfy every need.

2.28.2 Performance Characteristics

Tape Transport

Tape Speeds. Six speed: 60, 30, 15, 7-1/2, 3-3/4 and 1-7/8 ips; electrically selected with rotary switch.

Reels. 12-1/2 in. (31.8 cm) or 10-1/2 in. (26.7 cm) precision reels

Flutter. Percent measured per IRIG 106-71 (2 sigma)

Tape Speed (ips)	Bandpass (Hz)	Percent Flutter	Percent Flutter
[illegible]	0.2 - 10,000	0.30	0.40
[illegible]	0.2 - 5,000	0.32	0.60
15	0.2 - 2,500	0.35	0.80
7-1/2	0.2 - 1,250	0.40	1.50
3-3/4	0.2 - 625	0.6	1.80
1-7/8	0.2 - 312	0.7	2.0

Dynamic Skew. Measured between adjacent tracks on the same head stack.

Tape Speed (ips)	Skew (microseconds)	Skew (microseconds)
60	$\pm$0.5	$\pm$3.0
30	$\pm$1.0	$\pm$5.0
15	$\pm$2.0	$\pm$8.0
7-1/2	$\pm$4.0	$\pm$20.0
3-3/4	$\pm$6.0	$\pm$35.0
1-7/8	$\pm$12.0	$\pm$70.0

Time Base Error. Measured as the difference between crystal reference and capstan tachaometer. (No sync off tape provisions are included in this machine.)

Tape Speed (ips)	TBE (microseconds)
60	±1.0
30	±2.0
15	±4.0
7-1/2	±6.0
3-3/4	±8.0
1-7/8	±10.0

When reproduced in tape servo mode on an FR-2000 TBE will be less than ±0.6 microseconds at 60 ips.

Tape Speed Accuracy. ±0.2% maximum error in tachometer mode measured per IRIG 106-71.

Servo Control Track. Built-in 100 kHz reference standard at 60 ips; proportionately lower at lower tape speeds.

Fast-Wind Time. For 12-1/2 in. (31.8 cm) reel with 7200 ft (2.22 cm) of tape, less than 13 minutes.

Start Time. Time required from start command to meet flutter specifications is 5 seconds or less at 60 ips; lower at lower speeds.

Tape Specifications. Either 1/2 in. (1.28 cm) or 1 in. (2.56 cm) tape of 1 mil or 1-1/2 mil polyester base. Ampex tape type 772 on precision reels is recommended.

Heads. Head geometry per IRIG 106-71.

Direct Signal Electronics

Intermediate Band, Direct

Frequency Response and Signal-to-Noise:

Tape Speed (ips)	Bandwidth (+3 dB)**	SNR*1 Monitor (dB)	SNR*1 Ground Reproduce** (dB)
60	300 Hz - 300 kHz	33	36
30	150 Hz - 150 kHz	33	36
15	100 Hz - 75 kHz	33	36
7-1/2	100 Hz - 38 kHz	32	36
3-3/4	100 Hz - 19 kHz	31	36
1-7/8	100 Hz - 10 kHz	30	34

*1 Measured at the output of an 18 dB per octave filter using a 1 kHz signal at 60 ips, normal record level and 1% third harmonic distortion.

**Reproduced on an Ampex FR-2000 or equivalent monitor output response is ±4 dB.

Input Level. 0.25 to 4.0 volts rms

Input Impedance. 10K ohms ±10% in parallel with no more than 100 pf to ground.

Output. When used with reproduce leads and preamps: 30 dB of gain available; output is unequalized.

Wideband, Direct

Frequency Response and Signal-to-Noise

Tape Speed (ips)	Bandwidth (±3 dB)**	SNR*2 Monitor (dB)	SNR*2 Ground Reproduce** (dB)
60	400 Hz to 1 MHz	20	20
30	400 Hz to [illegible]0 kHz	18	20
15	400 Hz to 250 kHz	18	20
7-1/2	400 Hz to 125 kHz	18	20
3-3/4	400 Hz to 63 kHz	16	18
1-7/8	400 Hz to 31 kHz	15	17

NOTES

*2 Measured at the output of an 18 dB per octave filter using 100 kHz signal at 60 ips to set normal record level for 1% third harmonic distortion.

** Reproduced on an Ampex FR-2000 or equivalent; monitor output response is ±4 dB.

Input Level. 0.25 to 4.0 volts

Input Impedance. Selectable 1K ohm ±10% or 75 ohms ±10%

Output. When used with reproduce leads and preamps: 40 dB of gain available; output is unequalized.

FM Signal Electronics

Wideband Group II

Tape Speed (ips)	Center Carrier Freq (kHz)	Bandwidth*	Signal-to-Noise** Monitor (dB)	Signal-to-Noise** Ground Reproduce (dB)
60	216	dc - 250 kHz	29	32
30	108	dc - 125 kHz	28	31
15	54	dc - 62.5 kHz	27	30
7-1/2	27	dc - 31.25 kHz	26	29
3-3/4	13.5	dc - 15.6 kHz	23	26
1-7/8	6.75	dc - 7.8 kHz	22	25

*Frequency response down no more than -1 dB at 0.32 F_{co}, -4 dB at 0.8 F_{co} and -6 dB at F_{co}.
**RMS signal to rms noise ratio

Input Level. ±0.5 to ±5.0 volts for full deviation.

Input Impedance. 75 ohms ±5% shunted by 100 pf unbalanced to ground.

DC Drift. Less than ±0.5% of full deviation over any 10 C temperature change from -29 C to +55 C after 16-minute warmup. Less than 1.5% of full deviation over full temperature range.

DC Linearity. ±0.5% of total deviation measured per IRIG 106-71 at any temperature from -29 C to 55 C.

Harmonic Distortion. Less than 3% total for all frequencies up to 0.8 F_{CO}.

Tape Speed (ips)	Center Carrier Freq (kHz)	Bandwidth (± 1/2 dB)	Signal-to-Noise** Monitor (dB)	Signal-to-Noise** Ground Reproduce*** (dB)
WIDEBAND GROUP I				
60	216	dc - 40 kHz	46	48
30	108	dc - 20 kHz	45	48
15	54	dc - 10 kHz	43	46
7-1/2	27	dc - 5 kHz	43	44
3-3/4	13.5	dc - 2.5 kHz	40	43
1-7/8	6.75	dc - 1.25 kHz	38	41
INTERMEDIATE BAND				
60	108	dc - 20 kHz	46	49
30	54	dc - 10 kHz	45	48
15	27	dc - 5 kHz	43	46
7-1/2	13.5	dc - 2.5 kHz	43	46
3-3/4	6.75	dc - 1.25 kHz	41	44
1-7/8	3.375	dc - 625 Hz	40	43
LOW BAND				
60	54	dc - 10 kHz	46	49
30	27	dc - 5 kHz	45	48
15	13.5	dc - 2.5 kHz	43	46
7-1/2	6.75	dc - 1.25 kHz	43	44
3-3/4	3.375	dc - 625 Hz	41	44
1-7/8	1.6875	dc - 312 Hz	40	43

Note: **Rms signal to rms noise ratio.
***Reproduced on an Ampex FR-2000 or equivalent

Input Level. ±0.5 to ±5.0 volts for full deviation.

Input Impedance. 100K ohms ±5% selectable with jumper resistor in parallel with no more than 100 pf unbalanced to ground.

DC Drift. Less than ±0.5% of full deviation over any 10 C temperature change from -29 C to +55 C after 15-minute warmup. Less than ±1.5% total drift over full temperature range.

DC Linearity. ±0.5% of total deviation measured per IRIG 106-71 at any temperature from -29 C to +55 C.

Harmonic Distortion. Less than 2% total for any frequency up to 0.8 F_{co}.

2.28.3 Physical Characteristics

Size

18.7 x 17.5 x 7.0 in. (47.5 x 44.5 x 17.8 cm) including shock mounts and mating cable connectors

Weight

48 lb (21.8 kg) without tape for a 14-channel direct system; 61 lb (27.7 kg) without tape for a 14-channel FM system.

2.28.4 Suitability Analysis

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. Unit is well constructed machined aluminum chassis. Electronic assemblies are modular. Circuit boards are retained by spring clips (Figures 2.28-2 and 2.28-3).			
MATERIALS			
Mylar tape Aluminum Typical electronics unit Fiberglass phenolic circuit boards			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Vibration: Tested to levels specified in MIL-STD-810B Notice 1, Figure 514.1-2 curve D. Degradation in performance as noted. Specifications are for vibration in any axis.			
Shock: Recorder will meet full performance specifications after application of shock per MIL-STD-810B Figure 516.1-2 procedure I (15 g half-sine - 11 milliseconds) while operating. Recorder will meet crash safety requirements of procedure III of the above specification.			
Circuit board installation of spring clip type	X		
Wiring cables well tied down	X		
Internal and external connectors are positively locked type	X		
Push or transistor heat fins			X
Numerous calibration adjustments may move during vibration			X
Shock and vibration isolation devices are ringed spring steel (Figure 2.28-4)	X		
ELECTRICAL POWER			
Voltage: 24 to 28 v dc per MIL-STD-704A, Category B	X		
Power Consumption: 175 watts steady state maximum at 60 ips in the record mode with 14 tracks of direct record electronics. Less than 140 watts at 1-7/8 ips under the same conditions. Starting surges may be as high as 15 amps depending on configuration, input voltage, and tape pack radius. Below 10 C heaters consume an additional 250 watts.			

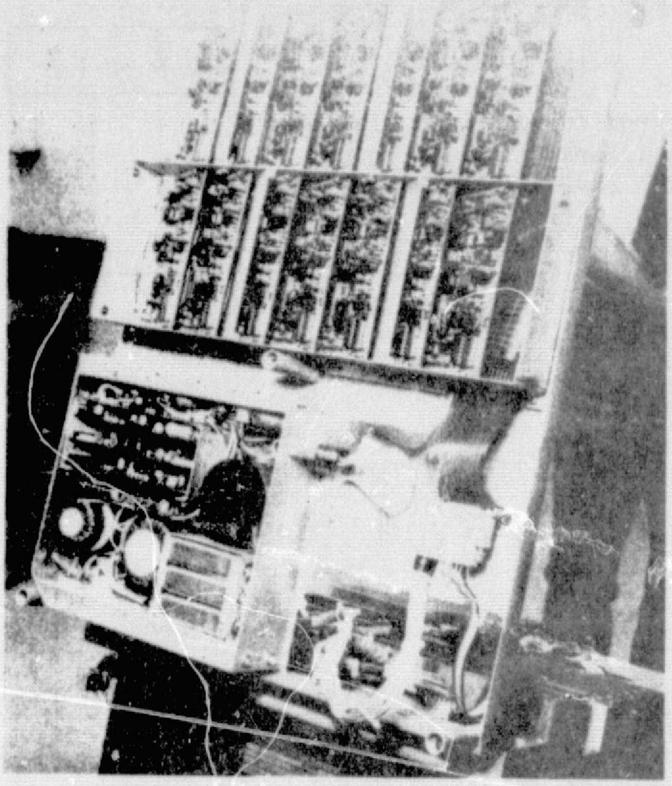

Figure 2.28-2.
Interior Circuit Board Arrangement

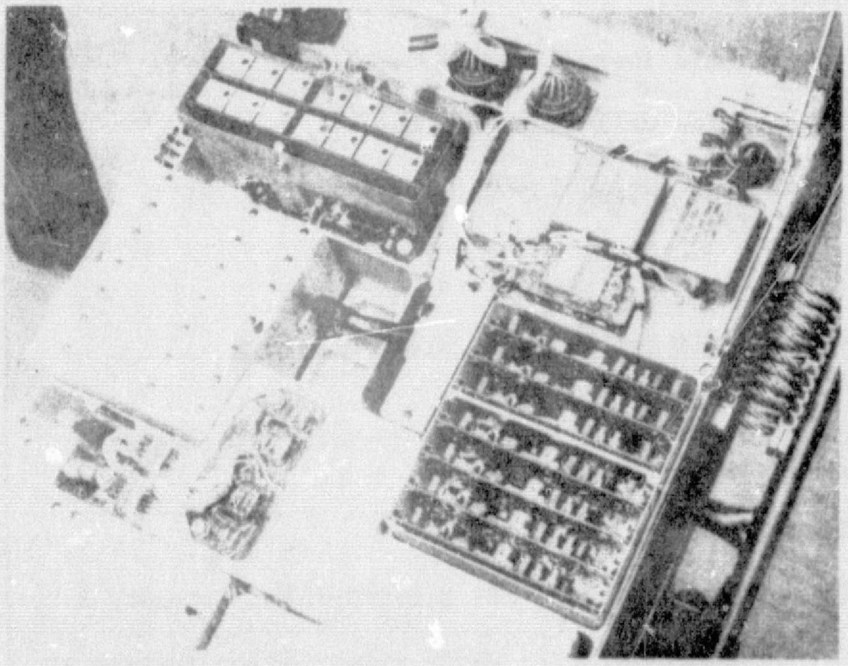

Figure 2.28-3. Modular Electronic Assemblies

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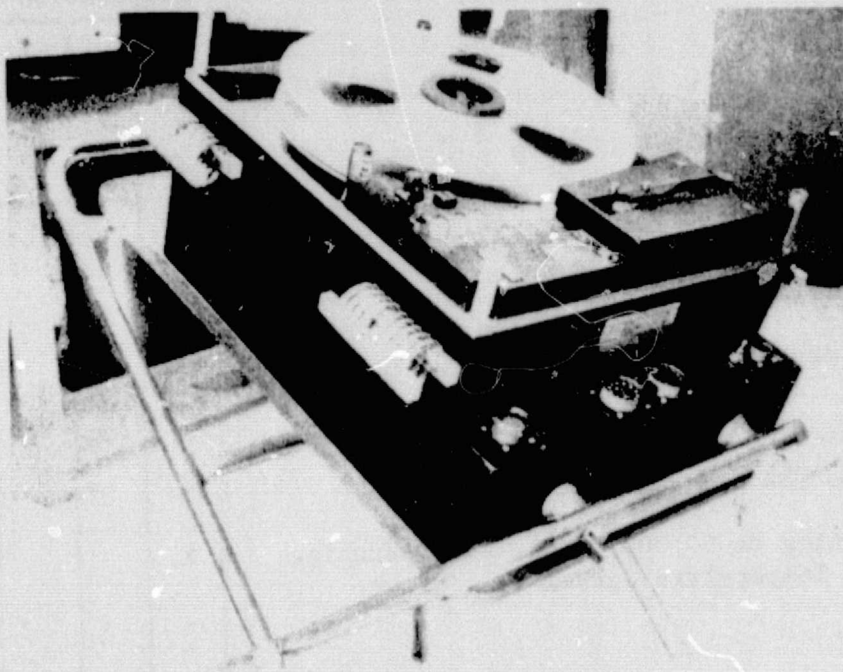

Figure 2.28-4. External View Showing Wire Shock and Vibration Attenuators

	Accept	Verify	Unaccept
DATA MANAGEMENT COMPATIBILITY			
± 5 V full scale input/output at low output impedances	X		
EMI SUSCEPTIBILITY AND RADIATION			
Electromagnetic interference: Tested to levels specified in MIL-STD-461. Levels may be exceeded at discrete frequencies depending on specific system configuration.	X		
NOISE GENERATION			
Fast forward and reverse cause air noise. Considered good indication unit is operational.	X		
FLAMMABILITY			
Mylar tape		X	
Sealed case	X		

	Disposition		
	Accept	Verify	Unaccept
TOXICITY			
No prohibited toxics or large quantities of potential generators identified.	X		
CONTAMINATION SUSCEPTIBILITY			
Rust can gum up magnetic tapes		X	
ATMOSPHERE			
Humidity: 30% to 95% non condensing	X		
Altitude: operating to 50,000 feet. Non-operating to 70,000 feet. Temperature derating as above.	X		
AMBIENT TEMPERATURE			
Temperature: Operating per MIL-E-5400L Class 1, except the lower temperature limit of the transport with tape shall be -29 C. Heater power must be applied one hour before operation below 4 C. Temperature shall be altitude derated per MIL-E-5400L, Figure 3, Sheet 1, Curve A.	X		
STORAGE: -54 C to 71 C without tape			
No degradation in system performance will be experienced due to temperature extremes.			
EQUIPMENT COOLING			
Unit can operate to 50,000 feet indicating external cooling as adequate. Skylab cooling approach also took heat out of external cover.	X		
ZERO-G EFFECTS			
Not gravity dependent	X		
OPERABILITY			
Sharp corners			X

2.28.5 Modifications

Construction

Shatterables. None

9-G Mounting/Integrity. Recorder is basicaliy strong enough to withstand this mode as regard to internal components; specification sheets so indicate. Unit weight is 75 lb (34 kg). Eight tapped holes for mounting are provided on the main casting. These are adequate for mounting.

Protrusions and Edges Safety. Fabricate cover per Figure 2.28-5 to cover instrument.

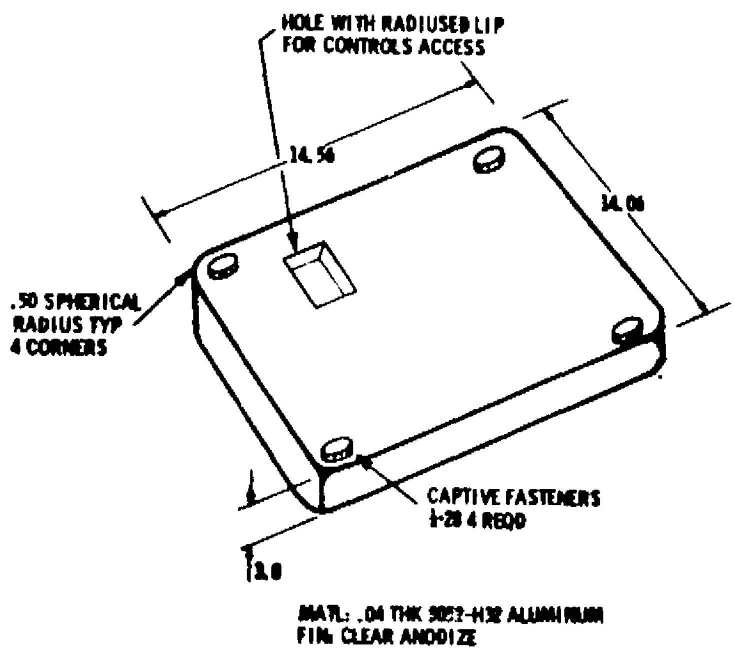

Figure 2.28-5. Tape Recorder Cover

19-Inch Rack Mount Capability. Fabricate 19-inch rack mount bracket per Design Guidelines.

Shock, Vibration, Acceleration, and Acoustics Resistance. Replace fasteners with CRES Nylok-type. Estimate250 fasteners. Cement approximately 42 transistor finned heat sinks (small amount of epoxy); apply Glyptal to 80 electrical adjustments.

Material Usage

Non-Prevelant Commercial Materials. Replace 7 pushbuttons with polyimide pushbuttons. Bake out unit 150 hours at 70 C to expel volatiles.

2.28.6 Cost Analysis

Modification

Basic Cost		$35,017
Modification Cost		
Fabrication	$ 6,034	
Engineering	8,979	
Test	4,416	
Documentation	2,160	
Program Management	1,616	
Total Modification Cost		$23,205
Total Cost		$58,222

New Development

Cost	$200,000
Weight	80 pounds
Complexity	--
State-of-the-Art Factor	--
Data Source:	Ampex quote

2.28.7 EC006M Delta Modification Requirements Summary

1. Provide for non-operating vacuum capability.
    a. Provide delta vacuum test chamber capability and test time (from 0.65 psia current to <1/10 psia) for qualification and acceptance.
    b. Respecify and replace 100 electronic parts for vacuum.
    c. Replace lubricants in capstan drive and reel motors and roller-actuator units.
2. Provide connector interface for all item-level testing.
    a. Add an external interface test connector (50-pin).
    b. Add a 50-wire test harness to approximately 50 assemblies.
    c. Patch wire 25 PCB's for 30 test signals to spare PCB connector pins.
    d. Add a hard-mounted signal isolation circuit board (20 discretes).
3. Seal the following connectors against moisture:
    a. 66 PCB-to-master interconnect board (note moulded plug-half of connector bolted to PCB's--not printed pins).
    b. 4 shell-type item interface connector halves.

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME Ampex Model AR-700 NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS: FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	EXPD.		COST $: MAT'L	LABOR	TOTAL
		PART ONE												
		Fab. Cover	1	3.00		.25						7.50		
		Fab. Rack Bracket		2.00		.20						12.50		
		Epoxy 42 Trans Fins			2.50	.50						2.50		
		Seal 80 Adjustments			5.00	.50						1.50		
		Fab. & Install Vespel Push-buttons	7	7.00	1.50	1.75						175.00		
		150 Hour Bake Out						16.00				500.00		
		PART TWO - Items Required to Perform Part One												
		Complete Disassembly, Including Detailed Doc. of Operation.			20.00			20.00	20.00					
		Reassembly			20.00	10.00		20.00	20.00					
		Calibration & Test					80.00		10.00					
		Calibration Certification				10.00	40.00	10.00						
		System Support						20.00		40.00		60.00		
		TOTAL HOURS		12.00	49.00	23.20	120.00	86.00	50.00	40.00		764.00		
		RATE O.H.												
		TOTAL										764.00	5270.24	6034.24
		TOTAL												
		TOTAL												

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4. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

5. Replace PVC as follows (delta to SEEIR modifications):

   a. Two branched harnesses (approximately 50 wires each--connector ends).

   b. Two harness (approximately 25 wires each, soldered in).

   c. Fifty loose wires (including those in sealed capstan drive unit).

6. Human factors modifications:

   a. Add captive one-quarter turn mounting fasteners (6).

   b. Add silkscreen operating instructions on panel (10 controls).

2.28.8 Delta Modification Costs

Fabrication	$ 4,840	
Engineering	29,679	
Test	5,594	
Documentation	2,562	
Program Management	2,133	
Total delta modification cost		$44,808

2.28.9 Data Sources

1. Visual examination

2. Operator/System Manual 1802014-02, AR-700 Airborne/Mobile Recorder; Ampex, March, 1971

2.29 TIME CODE GENERATOR

Manufacturer: Datatron Inc.

Model No.: 3150

Cost: $ 3220

Figure 2.29-1. Datatron Time Code Generator, Model 3150

2.29.1 Description

Model 3150 is a Universal Time Code Generator. The unit accumulates a BCD representation of days, hours, minutes and seconds from an internal frequency standard or from an external input. A high stability oscillator having a drift rate of less than 50 microseconds per day is available as an option. The 3150 can output up to five simultaneous serial time codes for recording on magnetic tape, film and/or oscillograph recorders, including two special multiple rate slew codes. A visual display of seconds, minutes, hours and days, a 42-bit parallel BCD output and pulse rates of 1000, 100, 10, and 1 pps are also provided.

2.29.2 Performance Characteristics

Standard Oscillator: Temperature controlled crystal oscillator. Aging rate ≤ 5 parts in 10^7/day. Temperature stability ≤ 5 parts in 10^6 from 0 to 50 C.

High Stability Oscillator (two types):

1. (Temperature controlled crystal oscillator. Aging rate $\leq$ 1 part in 10^8/day. Temperature stability ≤ 1 part in 10^6 from 0 to 50 C.)

2. (DC proportional oven. Aging rate ≤ 1 part in 10^9/day. Temperature stability ≤ 1 part in 10^8 from 0 to 50 C.)

Advance/Retard Logic: Enables accumulators to be advanced or retarded from 1 microsecond/secont to 100 milliseconds/second.

Auto Start: Energizing a pushbutton switch arms the unit to permit automatic start of the generator from an external pulse. A lamp indicates when generator is armed.

Preset Controls: Manual - provides initial time preset.

2.29.3 Physical Characteristics

Dimensions: 3-1/2" high x 19" wide x 20" deep (9 x 48 x 51 cm)

Weight: 12 pounds (5.5 kg)

2.29.4 Suitability Analysis

CONSTRUCTION. Rack mounted component also available as a 3/4 ATR package. Front nixie tube display covered by plastic shield. Large printed circuit board mounted on bottom plate. Large components are mounted to the side of the PCB (see Figure 2.29-2). Cantilever mounted "can".

	Disposition: Accept	Verify	Unaccept
MATERIALS			
Aluminum			
Plastic			
Mercury buffer in nixie tube			
Glass			
PVC wire insulation			
Fiberglass phenolic printed circuit board			
Black epoxy paint			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Circuit requires support to prevent oil-canning			X
Large 4" sealed can is cantilevered from front of chassis (see Figure 2.29-3)			X
Nixie tubes require support in sockets			X
ELECTRICAL POWER			
117 V ± 10%, 50 to 440 Hz, single phase 35 watts			
DATA MANAGEMENT COMPATIBILITY			
5 volts output; low impedance	X		
EMI SUSCEPTIBILITY AND RADIATION			
Internal shielding looks good. Coaxial outputs	X		
FLAMMABILITY			
Plastics used on front panel, Knobs			
PVC insulation			X
TOXICITY			
Mercury buffer in nixie tubes			X
CONTAMINATION GENERATION			
Nixie tubes may shatter and escape unit			X

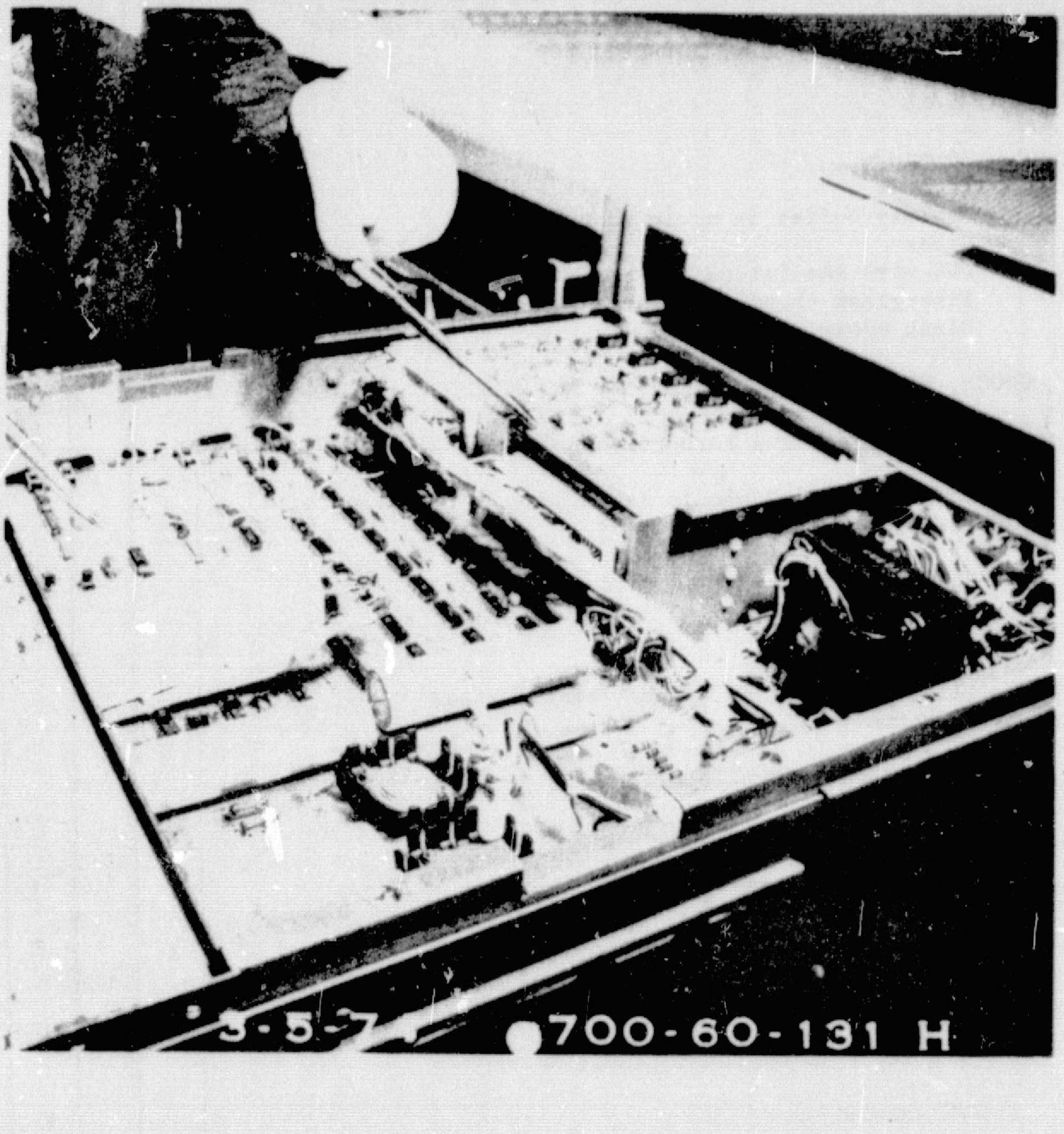

Figure 2.29-2. Datatron Timer Interior

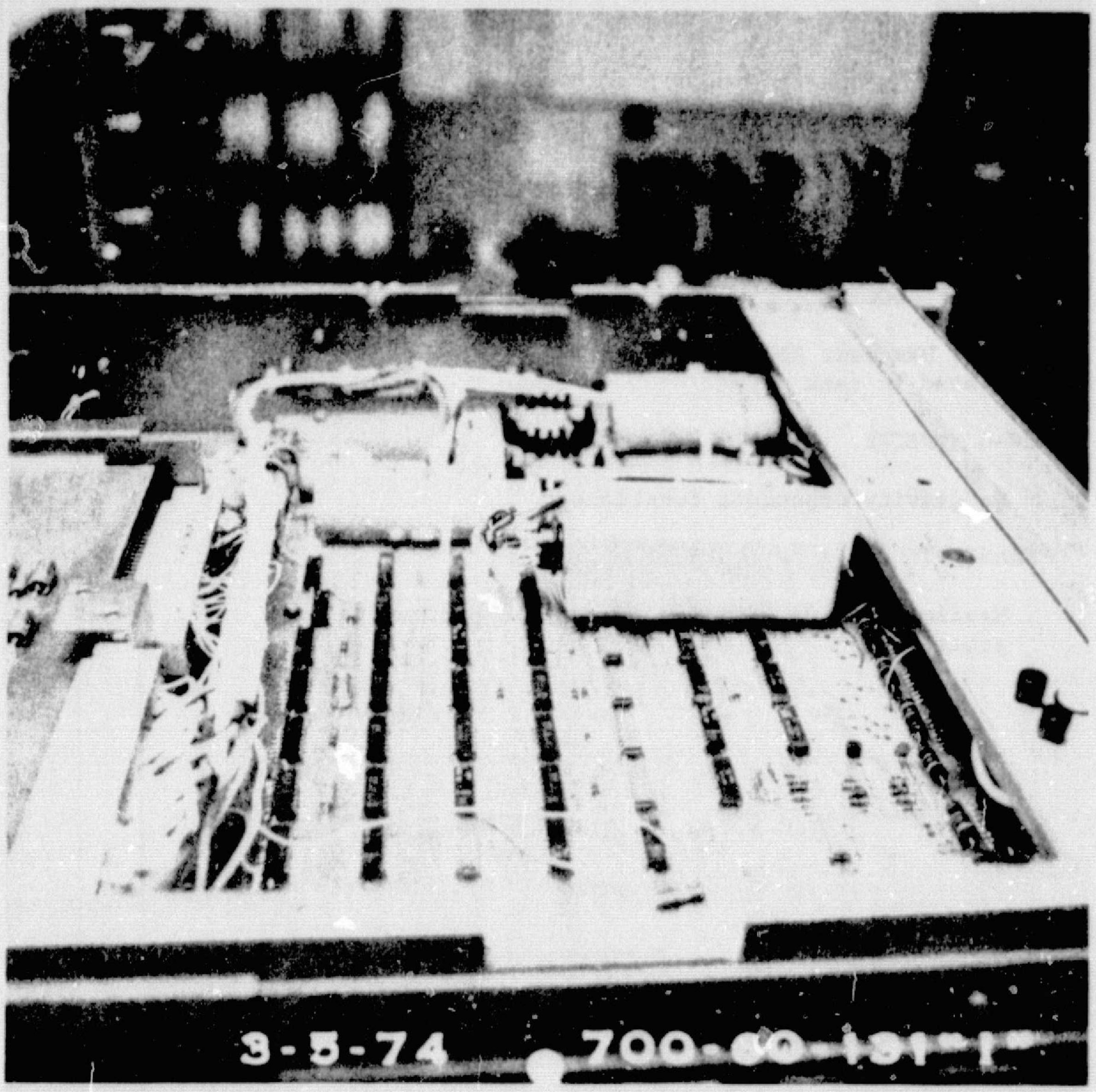

Figure 2.29-3. 4" Cantilevered Can

	Disposition		
	Accept	Verify	Unaccept
ATMOSPHERE			
Up to 95% relative humidity	X		
AMBIENT TEMPERATURES			
0 to 50 C	X		
EQUIPMENT COOLING			
Unit has vent holes for forced air cooling when placed in rack	X		
ZERO-G EFFECTS			
No gravity dependent functions	X		
OPERABILITY			
Handles require addition of rounded protrusion protection			X

2.29.5 Modifications

Construction

Shatterables.

1. Replace window with transparent Lexan material.

2. Cover inside of vents with metallic fine-mesh screen.

Protrusion Safety. Provide protrusion protection per paragraph 12.0 of Design Guidelines.

Shock and Vibration.

1. Conformally coat 2 P.C. boards. Secure circuit boards per paragraph 11.0 of Design Guidelines.

2. Secure 4-inch end-mounted can per Figure 2.29-4.

3. Secure nixie tubes per Figure 2.29-5.

4. Replace structural fasteners per paragraph 6.0 of Design Guidelines.

5. Secure unsupported lengths of wire per paragraph 2.0 of Design Guidelines.

Materials Usage

1. Replace panel knobs with Vespel.

2. Provide equivalent of 150-hour bakeout to expel off/out gas products.

3. Replace PVC insulated wire with TFE insulated wire (50 wires estimated).

2.29.6 Cost Analysis

Modification

Basic Cost		$ 3,697
Modification Cost		
Fabrication	$ 3,029	
Engineering	7,452	
Test	4,416	
Documentation	2,160	
Program Management	844	
Total Modification Cost		$ 17,901
Total Cost		$ 21,598

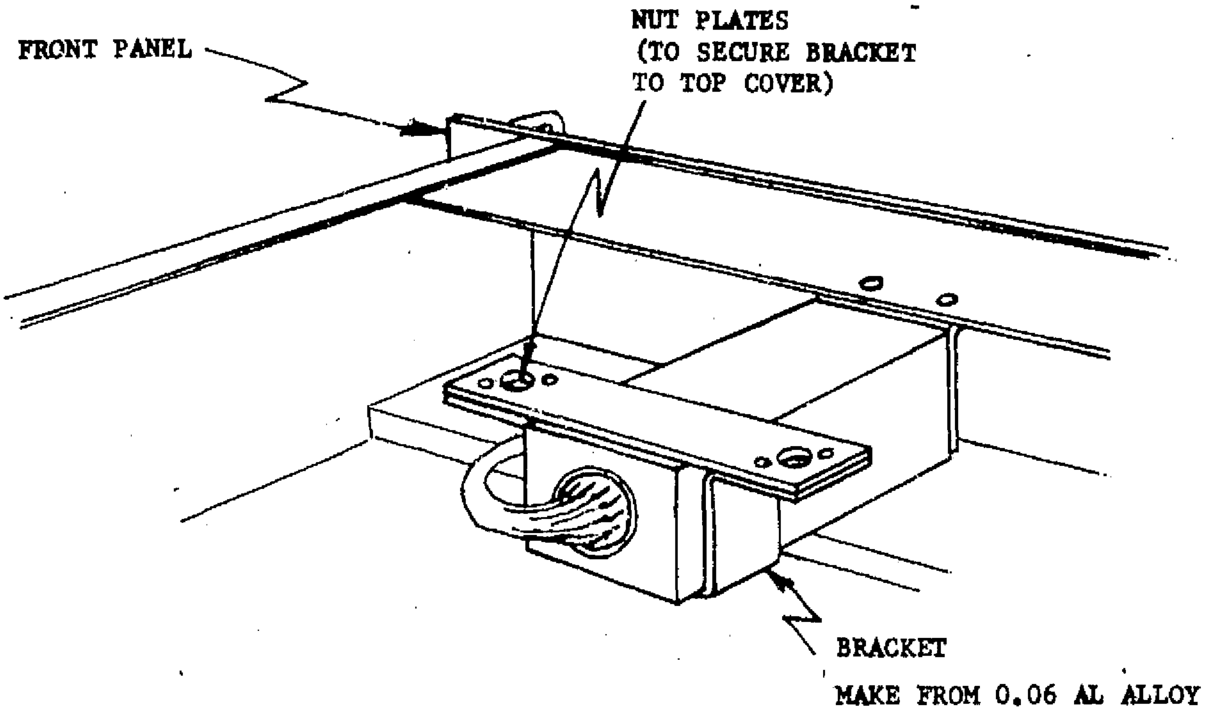

Figure 2.29-4. Securing Method - 4" Can

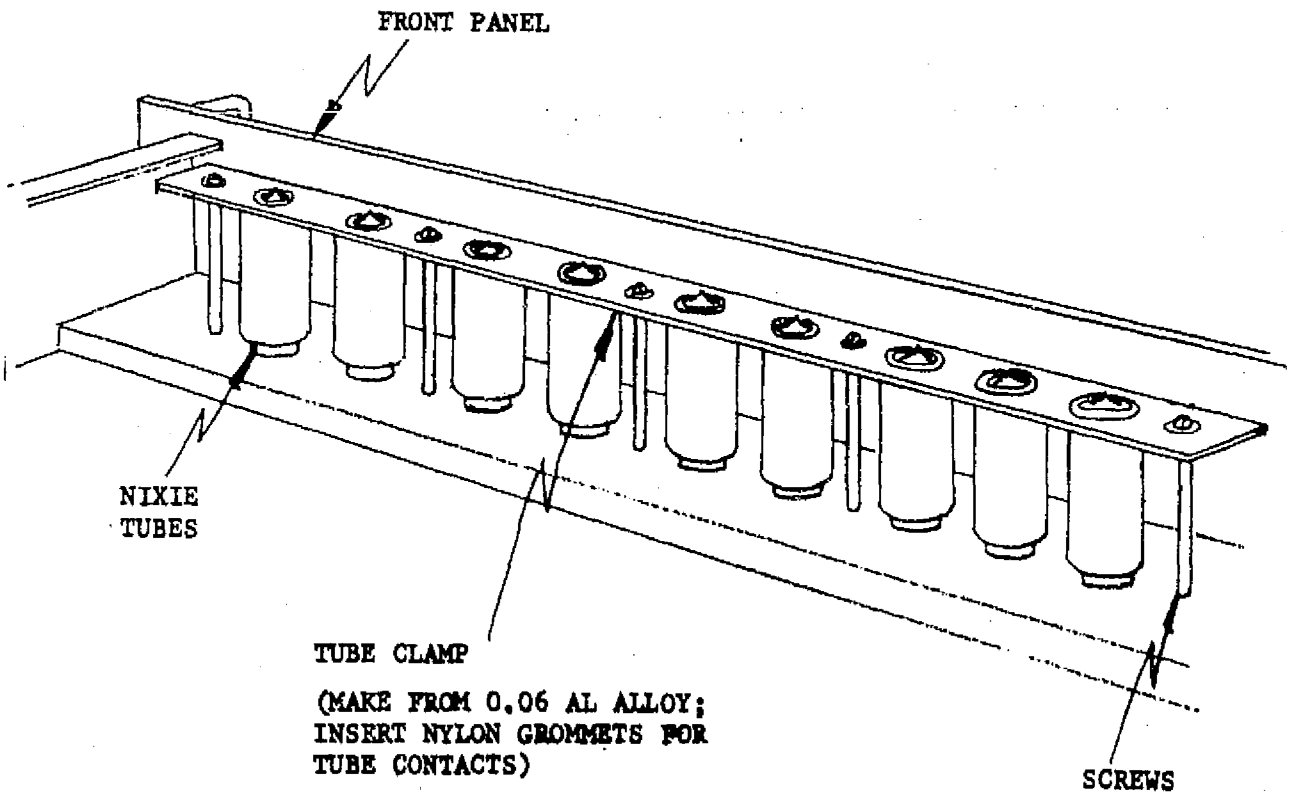

Figure 2.29-5. Securing Method - Nixie Tubes

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. DATATRON 3150 ASSEMBLY NAME Time Code Generator NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	FAB	ASS'Y	INSP.	TEST	M.E.	EXPD.				MAT'L	LABOR	TOTAL
		SECTION ONE DEFINED ITEMS													
		Lexan Front Window Fab. and Screws	1	1 00			10						15 00		
		Fab. & Install Fine CRES Screen	2	4 00		20							5 00		
		Fab. Rails Block & Pin Assys													
		Protrusion Protection	2	2 00		20							10 00		
		Secure 6 PCB's		10 00	2 00	2 00		4 00					10 00		
		Fab. Bracket & MOdify Cover	1	1 25		25							4 50		
		Fab. Bracket Drawing	1	1 00		25	10						5 00		
		Fab. Grommets		4 00			20						3 00		
		Conf Coat PCB	2		2 00	1 00	1 00	50					4 00		
		Replace all Hardware w/self-locking Type SS													
		This requires extensive											30 00		
		Disassembly & Reassembly			40 00	5 00									
		Secure & Tie Wrap Cables and Wires			4 00	1 00		1 00					5 00		
		Fab. New Panel Knobs - Vespel	8	8 00	1 00	60							200 00		
		Repl PVC Wire w/TFE	90		6 75	1 00		3 75					8 00		
		150 Hour Bake Out					10 00	10 00					350 00		
		Retest & Calibrate to Orig.Specs				20 00	20 00								
		General Support							20 00						
		TOTAL HOURS		34 75	48 25	29 85	85 30	15 00	20 00				649 50		

Beckman INSTRUMENTS, INC.	LOT SIZE FROM	TO	RATE	MAT'L	LABOR	TOTAL
			O.H.			
			TOTAL	649 50	2379 77	3029 27
			TOTAL			
			TOTAL			

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2-391

SD 74-SA-0047-3

Space Division
Rockwell International

New Development

Cost	$ 173,000
Weight	9 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Space Station - Central Timer

2.29.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and low (-40 F) temperature capability

   a. Respecify and replace 60 electronics parts for vacuum and thermal range

   b. Provide vacuum and -40 F thermal chambers and test time for acceptance and qualification testing

2. Provide connector interface for external item testing (to removable assembly level)

   a. Add a 25-pin interface test connector

   b. Add a 25-wire test harness to 5 PCB's and assemblies

   c. Patch wire test signals to spare connector pins (5 per PCB/assembly)

   d. Add a hardmounted test signal isolation circuit board (10 discretes)

3. Seal the following connectors/wiring junctions against moisture

   a. 8 rear and front panel BNC coax

   b. 2 rear panel BCD and remote control signal connectors

   c. 4 internal PCB to master board (printed pins)

   d. 0 internal cable junction

4. Replace PVC as follows (delta over SEEIR mods only)

   a. 25 loose wires

5. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

6. Provide following human factors redesigns

   a. Add captive 1/4 turn panel mount fasteners (4)

   b. Add silkscreen operating instructions on panel (10 controls)

2.29.8 Delta Modification Costs

Fabrication	$ 690	
Engineering	14,628	
Test	5,262	
Documentation	2,562	
Program Management	1,157	
Total delta modification cost		$ 24,299

2.29.9 Data Sources

1. Visual examination

2. Datatron Moving Up Fast in Timing Instrumentation, Datatron Inc.

3. Timing Instrumentation, Datatron Inc.

2.30 COUNTER-TIMER

Manufacturer:	Tennelec, Inc.
Model No.:	TC 545, TC 216, TC 909
Cost:	$ 1270

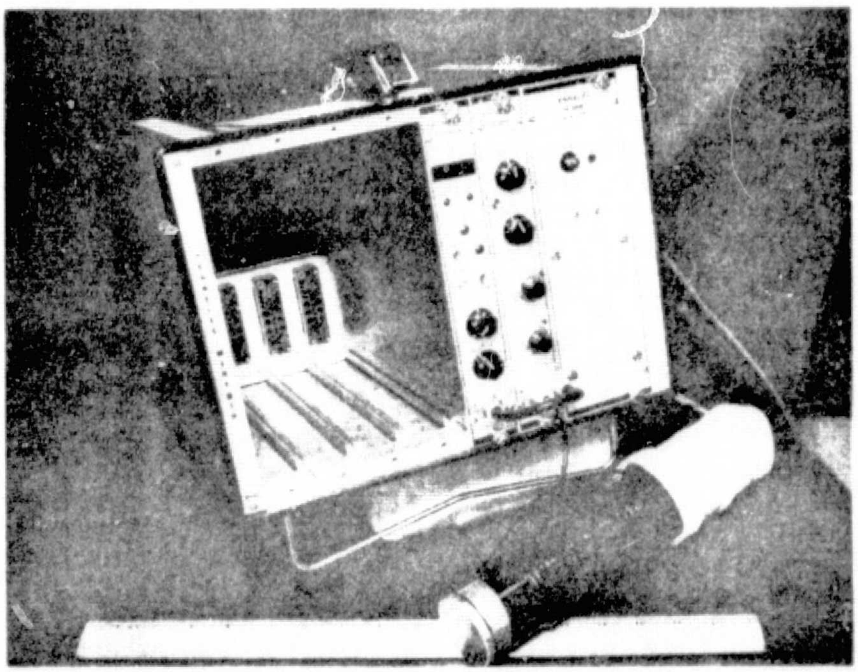

Figure 2.30-1. Tennelec Counter-Timer Assembly

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2.30.1 Description

Tennelec's TC 545 Counter-Timer, packaged in a single-width NIM module, consists of a six-decade, 20 MHz counter, and a five-decade preset timer. The TC 545 can be used in place of separate timer and scaler modules in a counting system and may act as system MASTER for controlling several other scalers. The counter section features a long-life columnar display, a 0.2V to 10V adjustable threshold and a front-panel gate input. The timer section features a switch-selectable 0.1 sec or 0.01 min timebase, one through nine preset, and rear-panel gate outputs. Also featured is a light-emitting-diode (LED) indicator which glows when the timer section is timing. Ordinary BNC cables are used to interconnect modules in a counting system. Since two Reset BNCs and two Gate BNCs are available (rear panel), no TEE connectors are needed.

2.30.2 Performance Characteristics

Counter Section

Count Capacity: 1×10^{-6} -1 (999,999) at a continuous count rate of 20 MHz.

Counter Input Characteristics: Positive polarity with minimum amplitude of 0.2V to 10V depending on THRESHOLD setting. Minimum required width is 20 nsec with no maximum width limitation. The minimum spacing between the trailing edge and leading edge of successive pulses is 30 nsec. The counter input terminal is dc-coupled, 1kΩ impedance.

Gate Input Characteristics: To enable counter, open circuit or greater than +2V is required; to disable counter, short to ground or less than +1.5V is required. (Source must sink ∿1mA). Required width is 100 nsec (minimum) with no maximum width limitation.

Timer Section

Timebase: Timebase is 0.1 sec or 0.01 min with timebase accuracy the same as the line frequency.

Presets: The 0.1 sec preset is selectable from 1 through 9 times: 0.1 sec, 1 sec, 10 sec, 100 sec, or 1000 sec (9000 sec maximum); the 0.01 min preset is selectable from 1 through 9 times: 0.01 min, 0.1 min, 1 min, 10 min, and 100 min (900 minutes maximum).

Gate Output Characteristics: Logic 1 is +6V. (Count-Stop switch in COUNT, timer ON: allows counting.) Logic 0 is less than 0.3V (current sink). (Count-Stop switch in STOP, timer OFF: disables counting.)

Reset Input/Output Characteristics: For input, open circuit or greater than +2V is required to not reset. To reset, short to ground or less than +1.5V is required. (Source must sink ∿1mA.) The minimum required width is 500 nsec with no maximum width limitation. For output, the reset causes the output to be shorted to ground for the length of time reset button is depressed.

2.30.3 Physical Characteristics

Timer-Counter

Dimensions - 1.35" x 8.714" x 10.75" (3.43 x 22.2 x 27.3 cm)

Weight - 2.6 pounds (1.18 kg)

Linear AMP and Scaler

Dimensions - 1.35" x 8.714" x 10.75" (3.43 x 22.2 x 27.3 cm)

Weight - 1.9 pounds (0.86 kg)

Power Supply

Dimensions - 2.70" x 8.714" x 10.75" (6.86 x 22.2 x 27.3 cm)

Weight - 10 pounds (4.54 kg)

2.30.4 Suitability Analysis

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. All modules are NIM-type construction. A single circuit board is mounted within each module. Aluminum panels enclose the circuit board on all sides. Controls are mounted on the front with a single multi-pin connector in the rear and BNC connectors in front panel. Each module is mounted in a NIM bin as shown in Figure 2.30-1.			
MATERIALS			
TFE wire harness VID Plastic shield over display Aluminum Fiberglass phenolic circuit board Plastic knobs			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Large circuit boards supported only at corners will oil-can in vibration (Figure 2.30-2)			X
Ceramic capacitors may have lead connection failures			X
Trim pots end mounted			X
Large lead mounted capacitors in power supply require support (Figure 2.30-3)			X
Wire bundles require tie down			X
Transistor push on heat sinks may come off in vibration			X
ELECTRICAL POWER			
Power Supply -			
103 to 130 V ac 50 or 60 Hz 206 to 257 V ac 50 or 60 Hz	X		
NIM Modules			
+24 V 80 mA +12 V 155 mA -24 V 80 mA -12 V 12 mA	X		
DATA MANAGEMENT COMPATIBILITY			
0-6 V logic output 0-5 V input	X		

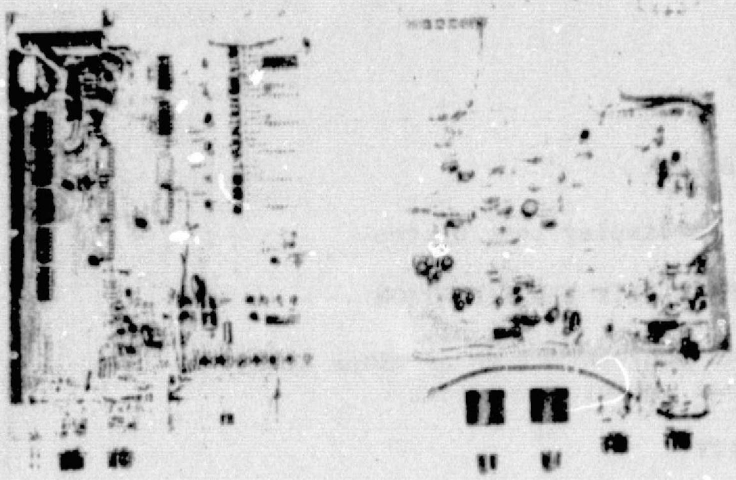


Figure 2.30-2. Interior View of NIM Module

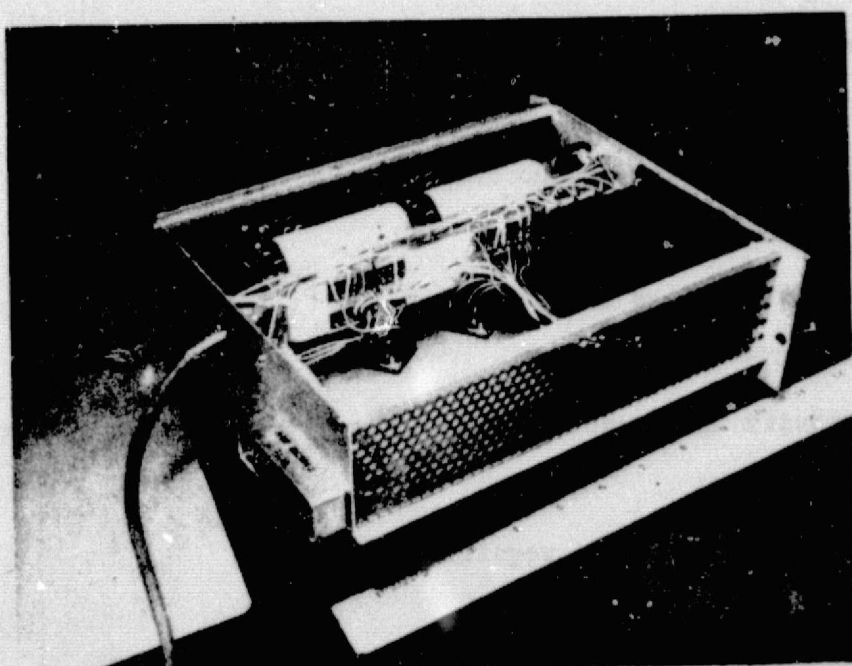


Figure 2.30-3. Interior of Power Supply Showing
Large Lead Mounted Capacitors

	Disposition		
	Accept	Verify	Unaccept
MAINTAINABILITY			
Built in display test button	X		
EMI SUSCEPTIBILITY AND RADIATION			
Screens and contact on aluminum slides Has coax output connectors	X		
FLAMMABILITY			
VID plastic knobs			X
Plastic display window		X	
TOXICITY			
None identified	X		
ATMOSPHERE			
Compatible with Spacelab environment	X		
AMBIENT TEMPERATURES			
Compatible with Spacelab temperatures	X		
EQUIPMENT COOLING			
Ported for forced air cooling	X		
ZERO-G EFFECTS			
No gravity dependent functions	X		
OPERABILITY			
Protrusion protection required			X

2.30.5 Modifications

Construction

Protrusion Protection. Install protection rails on rack cabinet per paragraph 12.0 of design guidelines.

Shock and Vibration.

1. Install circuit board stiffeners per Figure 2.30-4
2. Secure trimpot per Figure 2.30-5
3. Clip-support lead-mounted capacitors per paragraph 4.0 of design guidelines
4. Secure push-on transistor heat fins with epoxy adhesive
5. Replace structural fasteners per paragraph 6.0 of design guidelines

Materials Usage

1. Provide 150-hour off-gas bakeout

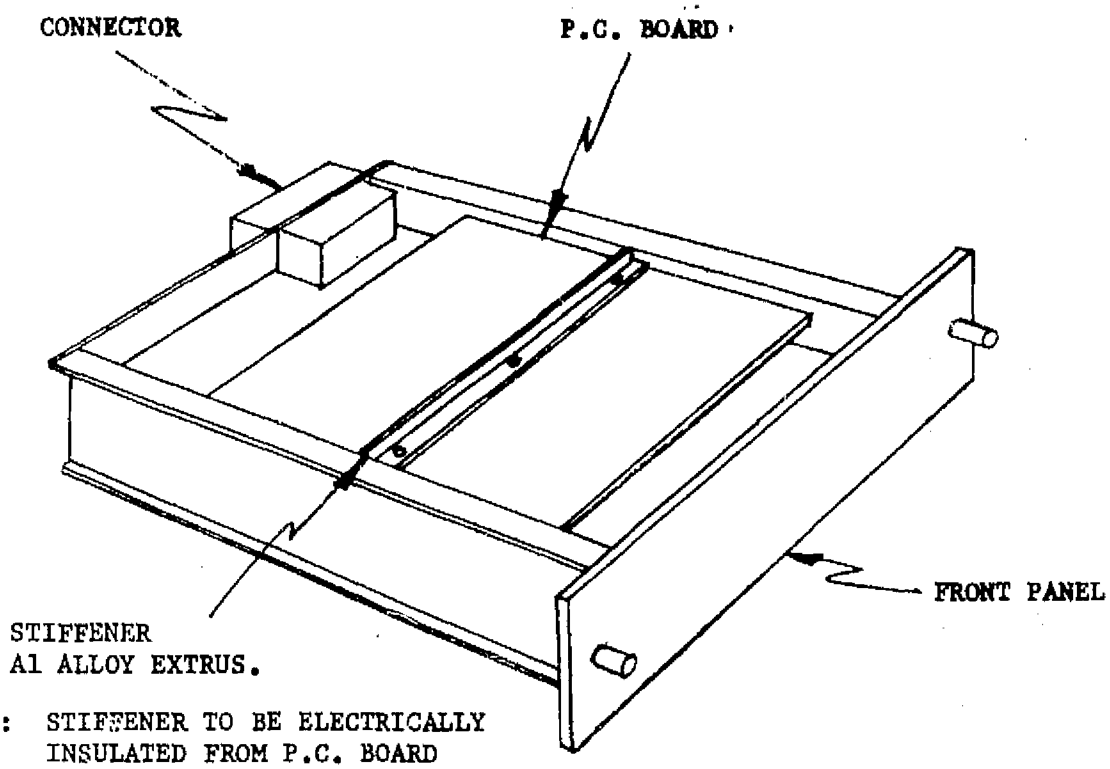
2.30.6 Cost Analysis

Modification

Basic Cost		$ 1,448
Modification Cost		
Fabrication	$ 1,129	
Engineering	4,453	
Test	4,416	
Documentation	2,160	
Program Management	607	
Total Modification Cost		$ 12,765
Total Cost		$ 14,213

New Development

Cost	$ 31,000
Weight	4 pounds
Complexity	0.40
State-of-the-art Factor	2
Data Source	Space Station Central Timer



NOTE: STIFFENER TO BE ELECTRICALLY INSULATED FROM P.C. BOARD

Figure 2.30-4. P.C. BOARD STIFFENING

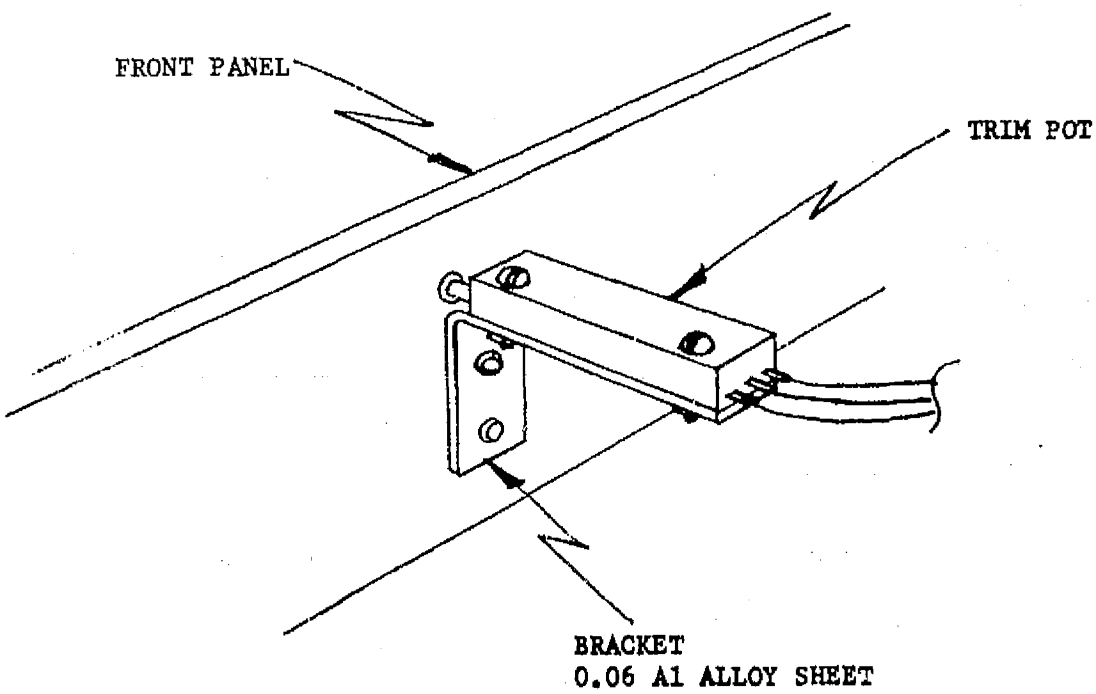


Figure 2.30-5. Trim Pot Support

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. Tennelec TC545A ASSEMBLY NAME Counter Assy NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	FAB	ASS'Y	INSP.	TEST	M.E.	MFG Tech	MAT'L	LABOR	TOTAL
		Protrusion Protection	2	2 00		20				10 00		
		Fab. and Install PCB Stiffen-ers	1	1 50	50	20				7 50		
		Secure Trimpot	1	1 00		10				3 80		
		Secure Capacitors	2	40	1 00	40				1 20		
		Epoxy on Heat SIngs	2		10	10				30		
		Replace Knobs	6	6 00	1 50	60				12 00		
		Conformally Coat PCB	1		1 00	1 00		1 00	50	2 00		
		Replace Fasteners			1 00	50		1 00		2 00		
		150 Hour Bake Out					10 00	10 00		350 00		
		Test and Calibration					5 00		5 00			
		TOTAL HOURS		10 90	5 10	3 10	15 00	12 00	5 50	388 80		
		LOT SIZE FROM / TO — RATE										
		O.H.										
		TOTAL								388 80	739 96	1128 76
		TOTAL										
		TOTAL										

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Space Division Rockwell International

2.30.7 EC006M Delta Modification Requirements Summary

1. Provide for non-operating vacuum (<1/10 psia) and thermal (-40 F to + 167 F) capability

   a. Respecify and replace 55 electronic parts for vacuum and temperature

   b. Provide vacuum and thermal test chambers and test time not now utilized for qual and acceptance

2. Provide connector interface for all item level testing

   a. Add a NIM bin test module with panel test connector (25 pin) and wiring to standard NIM module plug in connector

   b. Add patch wiring from PCB to module BIN connector spare pins (each of 3 modules; 5 wires each)

   c. Add rear NIM BIN connector test harness for 15 wires (solder into existing BIN connector receptacles)

   d. Within NIM BIN test module provide a hardmounted signal isolation circuit board containing 6 discrete electronic parts

3. Seal the following connectors against moisture

   a. 4 standard NIM BIN module plug-in connectors (includes the test module added above)

   b. 6 input/output coaxials (assumes experiment input is permanently connected over mission)

   c. 4 PCB connectors (all in TC 909 PIs) (printed pins)

4. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

5. Human factors mods as follows

   a. Add captive 1/4 turn panel mount fasteners on modules and bins (12 places)

   b. Add silkscreen operating instructions on panel (10 controls)

2.30.8 Delta Modification Costs

Fabrication	$ 725	
Engineering	11,187	
Test	5,382	
Documentation	2,562	
Program Management	995	
Total delta modification cost		**$ 20,869**

2.30.9 Data Sources

1. Visual examination
2. Tennelec Equipment Catalog, January 1972
3. Instruction Manual, TC 545 Counter-Timer, Tennelec
4. Specification Sheet TC 540A, Scaler, and TC 545A, Couter-Timer, Tennelec, February 1974

2.31 TRANSMITTER

Manufacturer:	RHG
Model No.:	FMT 1900 ATR
Cost:	$ 8,000

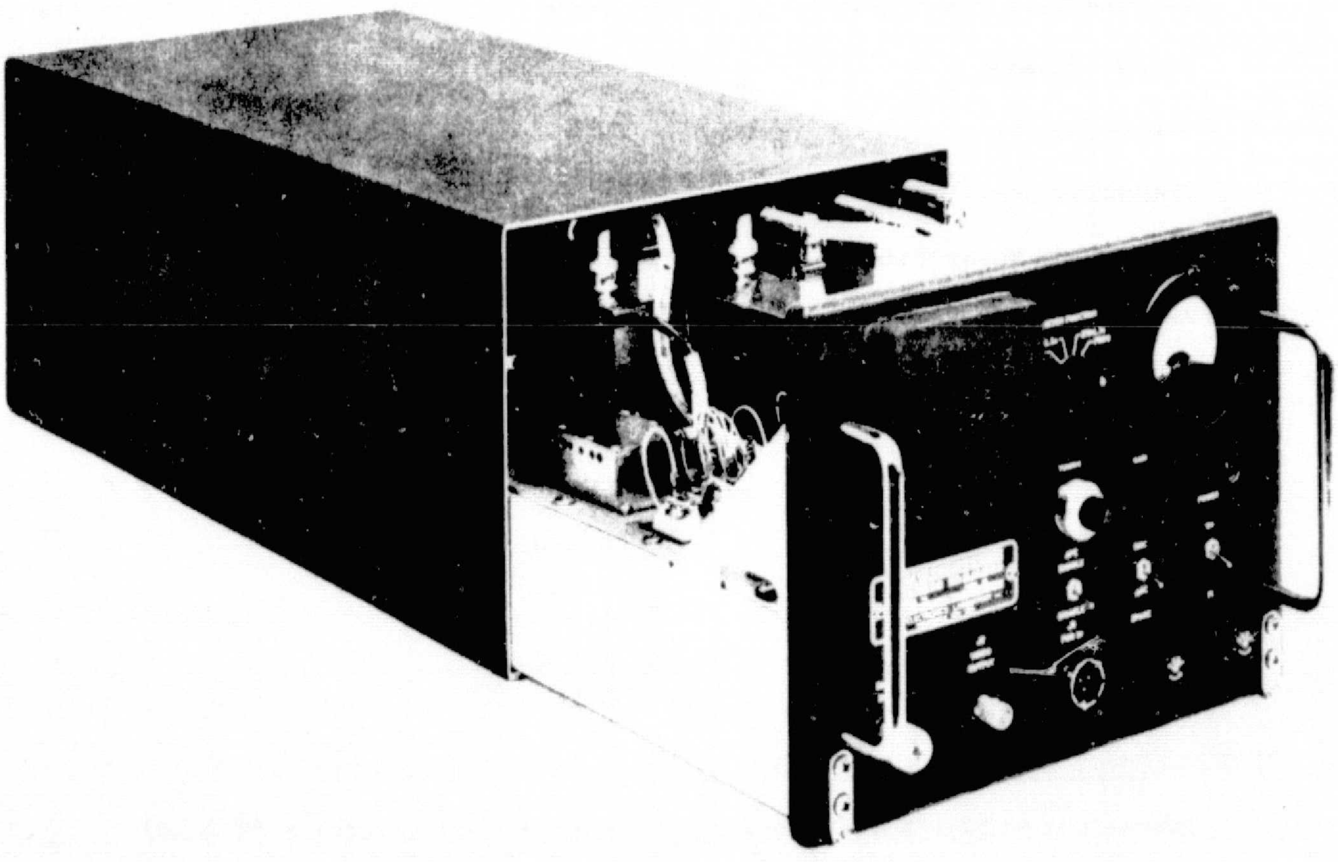

Figure 2.31-1. RHG Transmitter

2.31.1 Description

The FMT W1900 ATR incorporates a solid state, varactor tuned oscillator in the area of 350 MHz. The basic oscillator is deviated over wide limits with extreme linearity and fed to a power amplifier chassis which provides approximately 12 watts. A multiplier chain and high efficiency step recovery diodes provide the required power output at S band. A multipole filter and isolator follow. A low distortion video modulator and pre-emphasis network are included.

2.31.2 Performance Characteristics

Baseband Response:	±0.5 db, 10 Hz to 12 MHz (<2% tilt on 60 cycle square wave)
Differential Phase/Gain:	3°/±0.5 db
Output Frequency:	Fixed tuned in band of 1.4 to 2.3 GHz
Output Power:	2 watts minimum
Frequency Stability:	±0.05%
Modulation Bandwidth:	10 Hz to 12 MHz
Pre-Emphasis:	Per CCIR recommendation
Frequency Deviation:	Up to 18 MHz peak-to-peak
Modulation Sensitivity:	0.8 to 2 volts peak-to-peak (adjustable) produces full deviation
Spurious FM:	<50 kHz p-p
Incidental AM:	<1 db
Video Signal-to-Noise Ratio:	50 db p-p/RMS (at -40 DBM)

2.31.3 Physical Characteristics

Dimensions - 10-1/8 x 7-5/8 x 19-1/2 inches (25.7 x 19.4 x 49.5 cm)

Weight - 35 pounds (15.9 kg)

2.31.4 Suitability Analysis

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. ATR type construction. Internal construction consists of individual modules (see Figure 2.31-2). Uses stripline and hybrid techniques in sealed modules.			
MATERIALS			
Aluminum Plastic meter face High grade electronics components			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
The units are intended for airborne use in jet aircraft and meet MIL-E-5400 Class 1A.	X		
ELECTRICAL POWER			
Power required for the transmitter is 115 VAC 400 cycles and 28 VDC.	X		
DATA MANAGEMENT COMPATIBILITY			
Assumed compatible	X		
EMI SUSCEPTIBILITY AND RADIATION			
Fully RFI protected. Has grounded co-ax connector.	X		
NOISE GENERATION			
Fan has low noise	X		
FLAMMABILITY			
Unit is sealed	X		
TOXICITY			
Unit is sealed	X		
ATMOSPHERE			
Meets MIL-E-5400, Figure 6 - Curve A	X		
AMBIENT TEMPERATURE			
Meets MIL-E-5400, Figure 6 - Curve A	X		

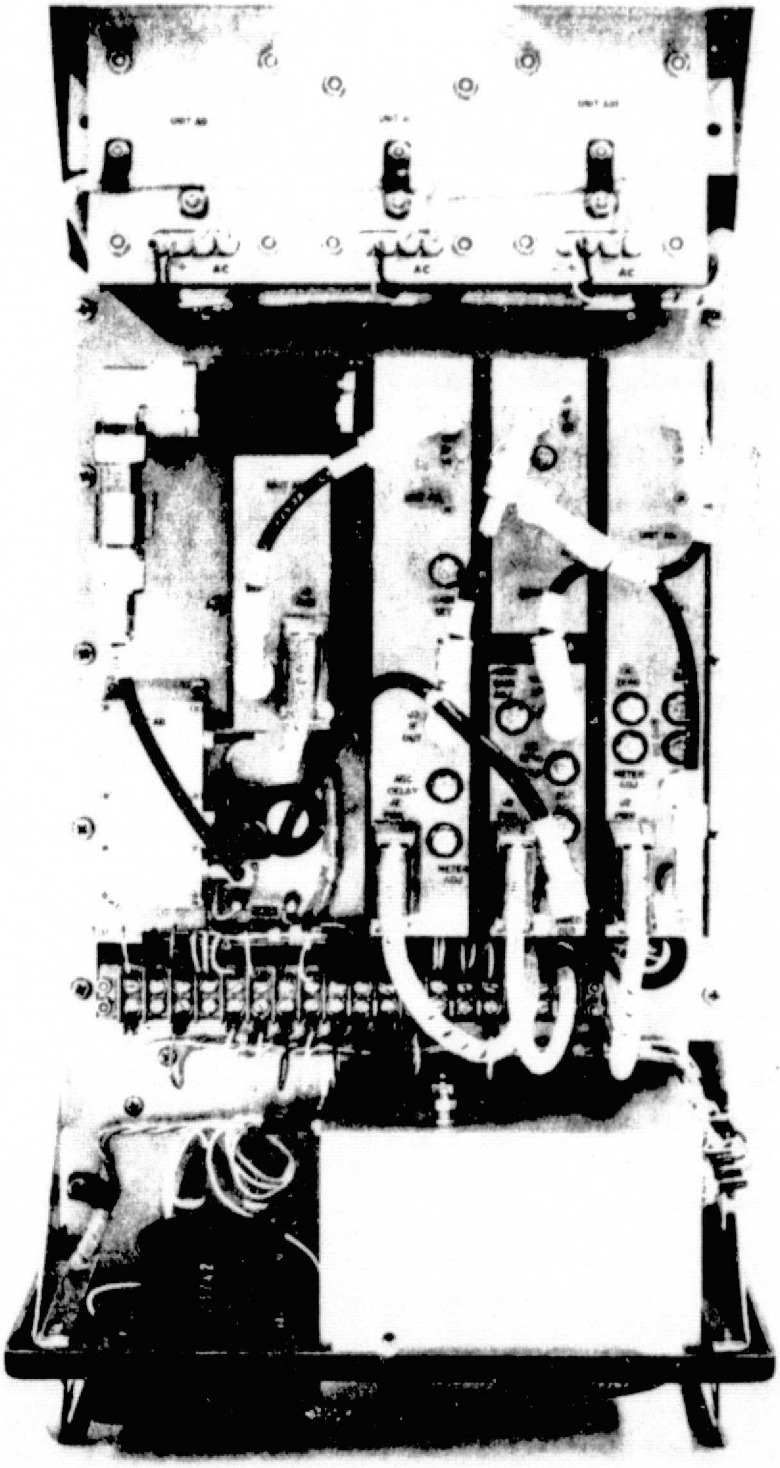

Figure 2.31-2. Standard ATR Configuration (Interior View)

	Disposition		
	Accept	Verify	Unaccept
EQUIPMENT COOLING			
Has internal fan	X		
ZERO-G EFFECTS			
None	X		
OPERABILITY			
Requires protrusion projection			X

2.31.5 Modifications

Construction

Protrusion Protection. Install protection rails on cabinet per paragraph 10.0 of Design Guidelines.

Materials Usage

Provide 150-hour off-gas bakeout

2.31.6 Cost Analysis

Modification

Basic Cost		$ 9,185
Modification Cost		
Fabrication	$ 835	
Engineering	2,392	
Test	2,944	
Documentation	2,160	
Program Management	417	
Total Modification Cost		$ 8,748
Total Cost		$ 17,933

New Development

Cost	$ 258,000
Weight	20 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter Communications

2.31.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating delta vacuum and thermal range capability
   a. Provide vacuum chamber and test time for qual and acceptance
   b. Replace fan lubricant
2. Provide external interface connector for testing item to replaceable assembly
   a. Add one 50-pin external interface connector
   b. Add a 50-wire test harness to 10 assemblies
   c. Add a hardmounted test signal isolation circuit board (20 discretes). Note: no mods required inside sealed assemblies

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. RHG Model FMT W1900 ASSEMBLY NAME L.X.C. - Band Transmitter NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	COST $ MAT'L	LABOR	TOTAL
		Fab. Protection Rails	2	2 00		20			10 00		
		150 Bake Out						16 00	500 00		
		TOTAL HOURS		2 00		20		16 00	510 00		

LOT SIZE FROM	TO	RATE		
		O.H.		
		TOTAL	510 00 (MAT'L)	325 00 (LABOR) / 835 00 (TOTAL)
		TOTAL		
		TOTAL		

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3. Seal the following connectors/wire junctions from moisture

   a. Three terminal strips (10 to 30 terminals each)

   b. (External and internal connectors already sealed)

4. Replace PVC as follows
   a. 50 loose wires

5. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

6. Human factors mods as follows

   a. Add captive 1/4 turn mounting fasteners (4)

   b. Add silkscreen operating instructions on panel (9 controls)

2.31.8 Delta Modification Costs

Fabrication	$ 424	
Engineering	17,664	
Test	4,876	
Documentation	2,562	
Program Management	1,276	
Total delta modification cost		$ 26,802

2.31.9 Data Sources

1. Bulletin 72B. RHG for Specialized Microwave Relay Links

2. Correspondence, R. B. Hirsch, President RHG to P. Fagan, Rockwell International, February 22, 1974

3. Catalog 72A. RHG. 1972

2.32 TRANSCEIVER

Manufacturer: Collins Radio

Model No.: 618M-2

Cost: $ 4500

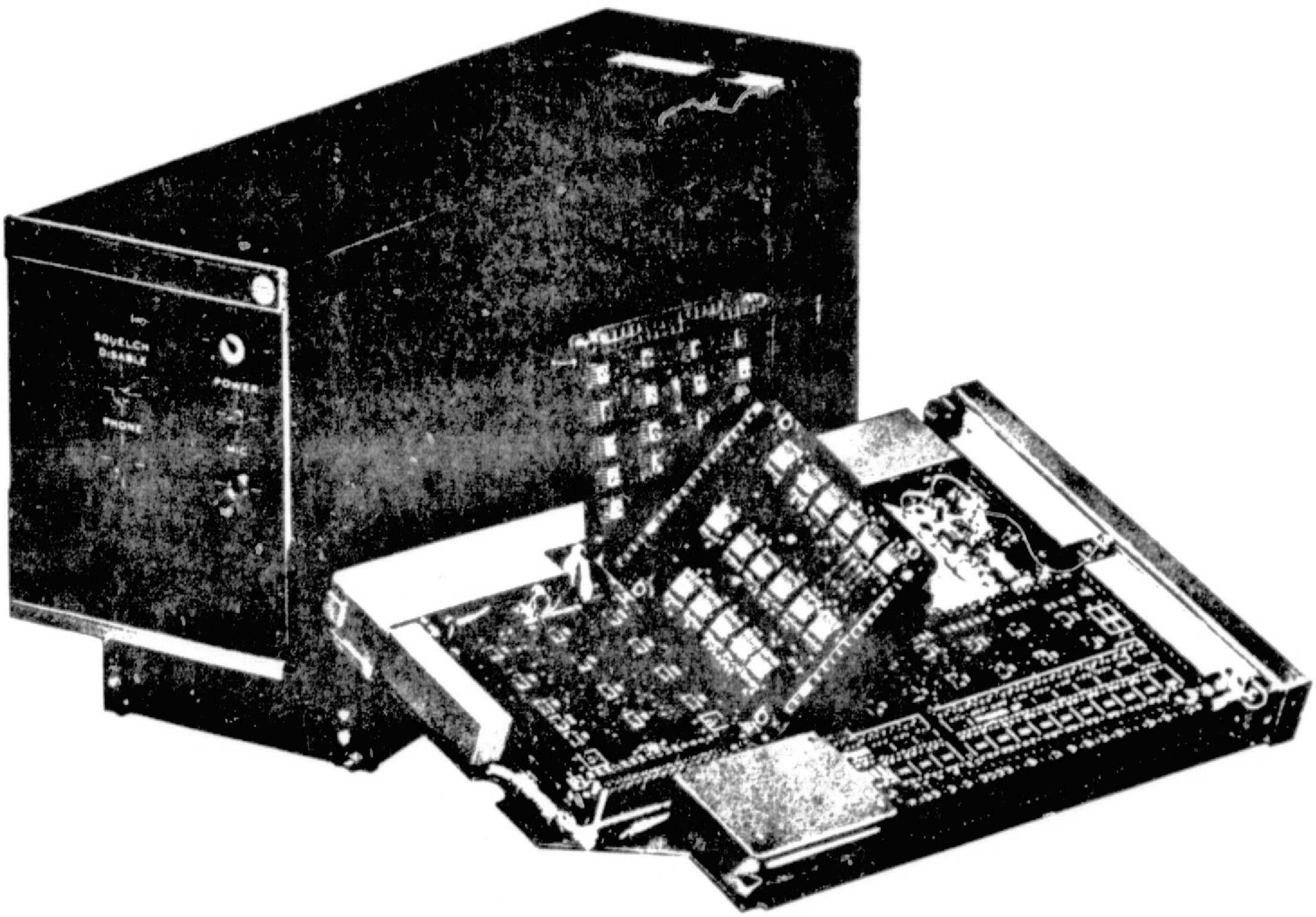

Figure 2.32-1. Collins Transceiver

2.32.1 Description

The Collins 618M-2B/D transceiver offers highly stable 25 kHz frequency spacing. Additional growth capabilities designed into the 618M-2B/D are digital frequency control and satellite communication system compatibility.

Frequency ranges available are 118.0-135.975 MHz (720 channels) in the 618M-2B, and 116.0-151.975 MHz (1440 channels) in the 618M-2D. Transmitter output is 25 watts minimum for the 618M-2B and 20 watts for the 618M-2D.

A single-crystal frequency synthesizer furnishes all receiver injection and transmitter excitation frequencies. This frequency generation device is compatible with both 25 kHz and 50 kHz two-out-of-five frequency selectors. By replacement of plug-in cards, the transceiver can be modified to frequency selection by serial control.

The transceiver circuitry is electronically and mechanically divided into frequency synthesizer, transmitter, and receiver units.

2.32.2 Performance Characteristics

Frequency:	618M-2B - 118.0-135.975 MHz (720 channels) 618M-2D - 116.0-151.975 MHz (1440 channels)
Frequency Stability:	$\pm$0.001%
Channel Spacing:	25 kHz (compatible with control units using 50 kHz spacing)
Frequency Control:	Two-out-of-five in accordance with ARINC Characteristic 410. Wire-saving serial control optional.
Design Specifications:	TSO C37B and C38b Env. Category $\frac{A}{D}$ A $\frac{A}{B}$ AAAE Class I ARINC Characteristics 546

Transmitter

Power Output:	618M-2B - 25 watts minimum 618M-2D - 20 watts minimum
Output Impedance:	50 ohms
Harmonic Content of Output:	60 db down from carrier minimum
Spurious Content of Output:	90 db down from carrier minimum

Audio Frequency Response:	6 db maximum variation, 300-3000 Hz
Modulation Capability:	90% amplitude modulation
Duty Factor:	Continuous at 30 C without cooling air
Audio Distortion:	10% maximum, 85% modulation

Receiver

Sensitivity:	10 db S+N/N for 3 uv signal; 30 db S+N/N for 100 uv signal
Bandwidth:	$\pm$14 kHz minimum at 6 db down $\overline{3}$3 kHz maximum at 60 db
AGC:	Maximum 5 db variation, 5-300,000 uv
Intermediate Frequencies:	18 MHz and 498.5 kHz
Undesired Responses:	90 db below desired signal
Input Impedance:	50 ohms
Audio Output:	100 mw with 30% modulated signal
Audio Frequency Response:	6 db maximum; 300-3000 Hz
Audio Compression:	3 db maximum increase in audio output for 20 db increase in input
Audio Distortion:	7% maximum, 30% modulation
ATCSS and SELCAL Audio Response:	6 db maximum variation, 300-22,000 Hz
Output Impedance:	600 ohms balanced and center tapped

2.32.3 Physical Characteristics

Size:

Standard 1/2 ATR short case

7-5/8" high x 4-7/7" wide x 14-11/16" long (19.4 x 12.4 x 37.3 cm)

Weight:

17.3 pounds (7.84 kg)

2.32.4 Suitability Analysis

	Disposition: Accept	Verify	Unaccept
CONSTRUCTION. Unit is an ATR-type module. Three segments are encased in an aluminum shell.			
Unit does not come with a 19-inch rack mount (uses ATR mounting).			X
MATERIALS			
Aluminum Fiberglass phenolic circuit board			
SHOCK, VIBRATION, ACCELERATION, AND ACOUSTIC ENVIRONMENT			
Shock: Rigid Mount - 6 g operational			
Well constructed. Transformer centrally mounted	X		
ELECTRICAL POWER			
Receive - 27.5 v dc, 1.2 amps Transmit - 27.5 v dc, 7 amps	X		
MAINTAINABILITY			
Has self test connector	X		
EMI SUSCEPTIBILITY AND RADIATION			
RFI gasketed	X		
Inspection indicates good practice followed	X		
FLAMMABILITY			
Unit is sealed	X		
TOXICITY			
No prohibited toxics or large quantities of potential generator identified.	X		

	Disposition		
	Accept	Verify	Unaccept
ATMOSPHERE			
Humidity: 95%	X		
Altitude: 55,000 ft			
AMBIENT TEMPERATURE			
-54 to +55 C. Up to +71 C short time operation (30 minutes)	X		
EQUIPMENT COOLING			
Unit can conduct heat adequately at an altitude of 55,000 ft. Placement in forced air rack with air blowing over external surface is only requirement.	X		
ZERO-G EFFECTS			
No gravity dependance	X		
OPERABILITY			
Rack mounting must protect against corners of module			X

2.32.5 Modifications

Construction

9 G Mounting/Integrity. The transceiver case is a standard "1/2 ATR Short" (ARINC) with an extended front panel. To convert it to a rack-mounting configuration, a modified NIM approach will be used, as follows:

1. A front panel (6.776 x 8.714 x 1/8 Al alloy) is attached to the front panel of the transceiver (ref. Figure 1 of Design Guidelines). In addition, two side panels are added of which the top and bottom edges serve as runners, mating with the guides in the NIM. The side panels are ported as required for ventilation, access, etc.

2. To accept the converted NIM transceiver module, the rear connector mounting plate of a standard 8-3/4" NIM bin is removed in the area where the over-long case protrudes through.

Materials

Provide the equivalent of an 150-hour bake out to expell out-gas products.

2.32.6 Cost Analysis

Modification

Basic Cost		$ 5,166
Modification Cost		
Fabrication	$ 1,302	
Engineering	3,128	
Test	2,944	
Documentation	2,160	
Program Management	477	
Total Modification Cost		$ 10,011
Total Cost		$ 15,177

New Development

Cost	$ 219,000
Weight	17 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Shuttle Orbiter Communications

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. Collins 618 MZ ASSEMBLY NAME VHF Transceiver NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	COST $ MAT'L	LABOR	TOTAL
		Fab. Front Panel		20 00		2 00			35 00		
		Fab. Side Panels	2	5 00		50			10 00		
		Remove Conn. Mtg. Plate		2 50	2 00	1 00		1 00			
		150 Hour Bake Out						16 00	500 00		
		TOTAL HOURS		27 50	2 00	3 50		17 00	545 00		

LOT SIZE FROM	TO	RATE	COST $ MAT'L	LABOR	TOTAL
		O.H.			
		TOTAL	545 00	756 84	1301 84
		TOTAL			
		TOTAL			

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2.32.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum and thermal range delta capability
   a. Respecify and replace 100 electronics parts for vacuum capability
   b. Add vacuum chamber and test time for qual and acceptance
2. Provide external interface test connectors to test item to replaceable assembly level
   a. Add one 50-pin external test connector
   b. Add one 50-wire test harness
   c. Add one hardmounted test signal isolation circuit board (20 discretes)
3. Seal the following connectors/wire junctions against moisture
   a. 6 PCB connectors (no printed pins)
   b. 2 external input/output connectors
4. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**
5. Replace PVC as follows (delta over SEEIR mods)
   a. Three 33-wire harnesses
   b. 50 loose wires
6. Human factors mods as follows
   a. Add silkscreen operating instructions to panels (6 controls)

2.32.8 Delta Modification Costs

Fabrication	$ 907	
Engineering	22,466	
Test	5,318	
Documentation	2,562	
Program Management	1,563	
Total delta modification cost		$ 32,816

2.32.9 Data Sources

1. Visual inspection

2. Collins 618M-2B/D - VHF Transceiver. Specification Sheet. Collins Radio Co. 8/72.

3. Collins 618M-2B/D. Maintenance Manual. Collins Radio Co.

2.33 COMMERCIAL VOLTMETER

Manufacturer: John Fluke Manufacturing Co., Inc.
Model Number: 8200A
Cost: $995

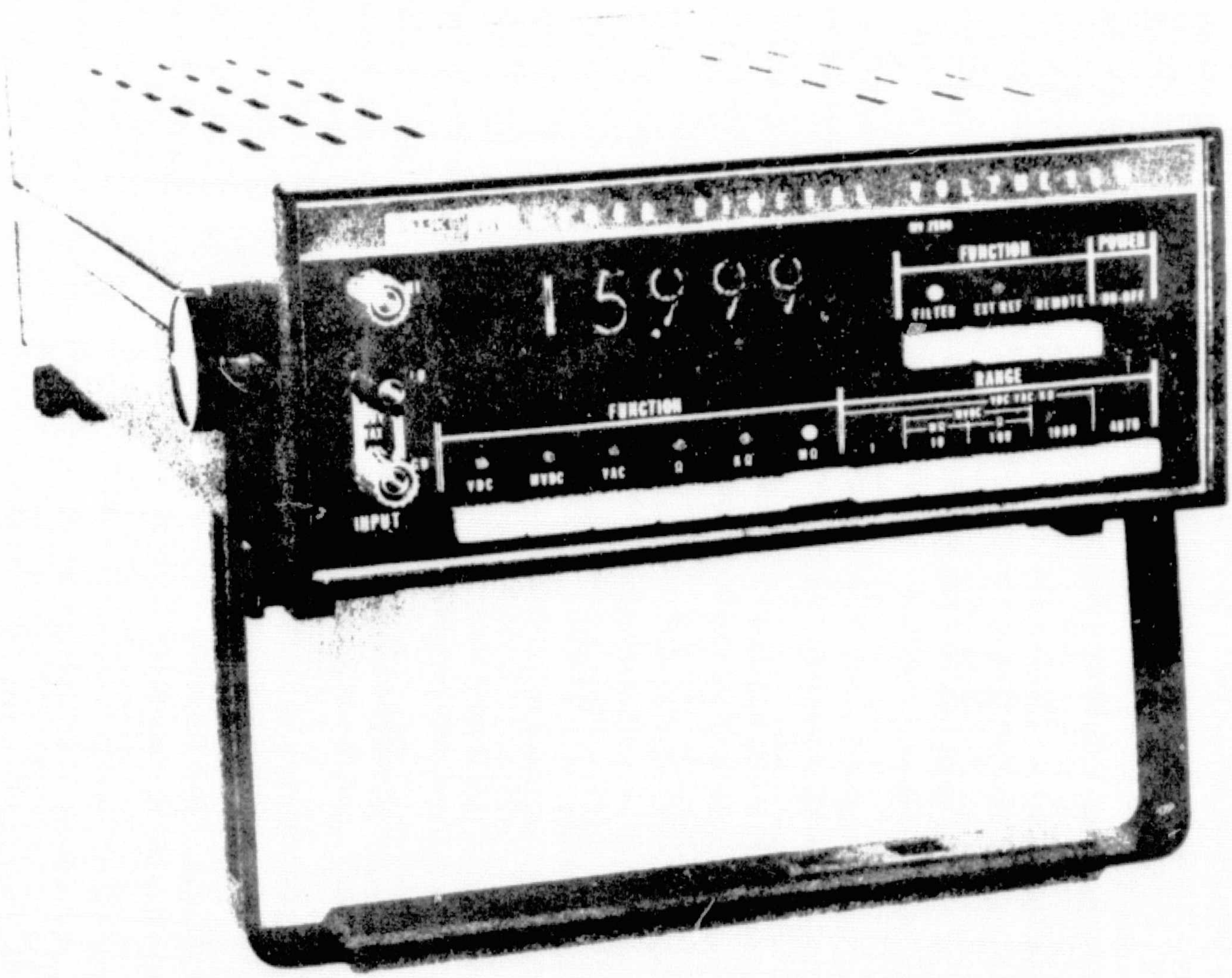

Figure 2.33-1. Fluke Digital Voltmeter - Model 8200A

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2.33.1 Description

The Model 8200A is a four-range dc DVM that can easily be expanded into a 400 readings per second systems multimeter by installing a family of plug-in options. Standard features of the basic instrument include 60-percent over-range, a switched filter for assured broadband noise rejection, all push button selection, autoranging, automatic polarity selection and display as well as full guarding. The in-line, non-blinking readout displays polarity, the over-range digit and four full decades of digits with automatic decimal point location. Illuminated indicators designate the function selected.

2.33.2 Performance Characteristics

DC Volts

Ranges	±1V, ±10V, ±100V, ±1000V (automatic polarity selection)
Resolution	0.01% of range, (100 uv, maximum on ±1V range)
Over-Range	60% (±1200V maximum input on ±1000V range)
Overload (without damage)	±1200V dc or 1100V rms continuously applied

Accuracy (To 160% of range or ±1200V maximum input)

90 days, 18 C to 28 C:	±(0.01% of input +0.01% of range)
1 year, 18 C to 28 C:	±(0.02% of input +0.03% of range)

Temperature Coefficient

10 C to 18 C and 28 C to 50 C	±(0.001% of input + 0.001% of range)/°C

Input Impedance, ±1V range	10,000 megohms, minimum shunted by less than 130 p.f.
±10V to ±1000V range	10 megohms ±0.2%
Input Offset Current	Less than 50 pa

Noise Rejection

Normal Mode, Filter "in"	Greater than 60 dB @ 50 Hz increasing to greater than 65 dB @ 60 Hz and 100 dB @ 200 Hz and above.
Common Mode, dc to 60 Hz, filter "in"	Greater than 140 dB (1k ohm lead unbalance; filter "out" - greater than 110 dB or ±1 digit (whichever is greater; 100 ohms lead unbalance)

Note: Common Mode Rejection specifications are maintained with any combination of options installed and are unchanged with the use of grounded devices with the remote control, data output or printer output options.

Response Time (To a reading within 0.01% of range when measuring step change inputs and using external trigger)

Filter "out"

Series of steps on same range	2.25 ms (3.75 ms, for first reading in series)*
Single reading	3.75 ms.
Filter "in"	500 ms (single reading or series of steps)

*Note: Includes buffer amplifier settling time of 2 ms, maximum to within 0.01% of input step.

General

A/D Conversion Technique	Recirculating-remainder
Digitizing Time	2.5 milliseconds
Sample Aperture	500 microsec. (at A/D converter input)
Sample Rate, External Trigger**	400 readings per sec max for all functions
Internal Trigger	4 readings per sec, basic DVM
Autorange Time (per range change) External Trigger**	25 millisec: MV/VDC and ohm/Kohm/Mohm, filter "out"; 250 millisec all other combinations
Internal Trigger	250 millisec

**Note: External triggering is accomplished via data output or printer output options

Filters	4 pole active filter for dc volts, and resistance measurements
Range Selection	Manual, automatic standard, remote optional
Function Selection	Manual standard, remote optional, autorange MVDC/VDC, ohm/Kohm/Mohm
Function Annunciator	Lamp indicator for each function selected
Display	In-line, neon-tube display of polarity, over-range digit and 4 full decades of digits with automatic decimal placement

Overload Limits (maximum voltage that may be continuously applied without damage)

"Hi" to "Lo"	See individual functions under "range," "overload"
"Lo" to "Guard"	±100V dc or peak ac; Note - a protection circuit causes a warning lamp to illuminate when this limit is exceeded.

"Guard" to "Chassis"	±1000V dc or peak ac, maximum common mode voltage for any function.

2.33.3 Physical Characteristics

Weight: Less than 15 lb (6.8 kg)

Dimensions: 3-1/2 in. (8.8 cm) high x 8-1/2 in. (21.6 cm) wide x 15 in. (38.1 cm)

2.33.4 Suitability Analysis

Item	Disposition: Accept	Disposition: Verify	Disposition: Unaccept
CONSTRUCTION			
Sheet - aluminum construction			
Can be obtained in 19-inch rack-compatible configuration.			
Uses nixie tubes for digit indication; neon lamps for lighting. See Figure 2.33-2.			
MATERIALS			
Chromated aluminum inner shell Glass nixie and neon tubes ABS PVC Fiberglass Royalite			
SHOCK, VIBRATION, ACCELERATION AND ACOUSTIC ENVIRONMENT			
Spec.			
Shock and vibration: meets requirements of MIL-T-21200H and MIL-E-16400F		X	
Visual Examination			
Long circuit boards require improved support. See Figures 2.33-3 and 2.33-4.			X
Screw and bolts require positive retention.			X
Neon tubes supported on leads.			X
Push-in components have no retention. See Figure 2.33-5.			X
Nixie tubes are supported only by basic connections.			X
ELECTRICAL POWER			
Power form: 115/230V $\pm$10%, 50 to 440 Hz	X		
Power demand: Less than 25 watts	X		
DATA MANAGEMENT COMPATIBILITY			
0 to 5V output logic available.	X		
EMI SUSCEPTIBILITY AND RADIATION			
Nixie tubes require shielding.			X
Has common mode guard shield.	X		

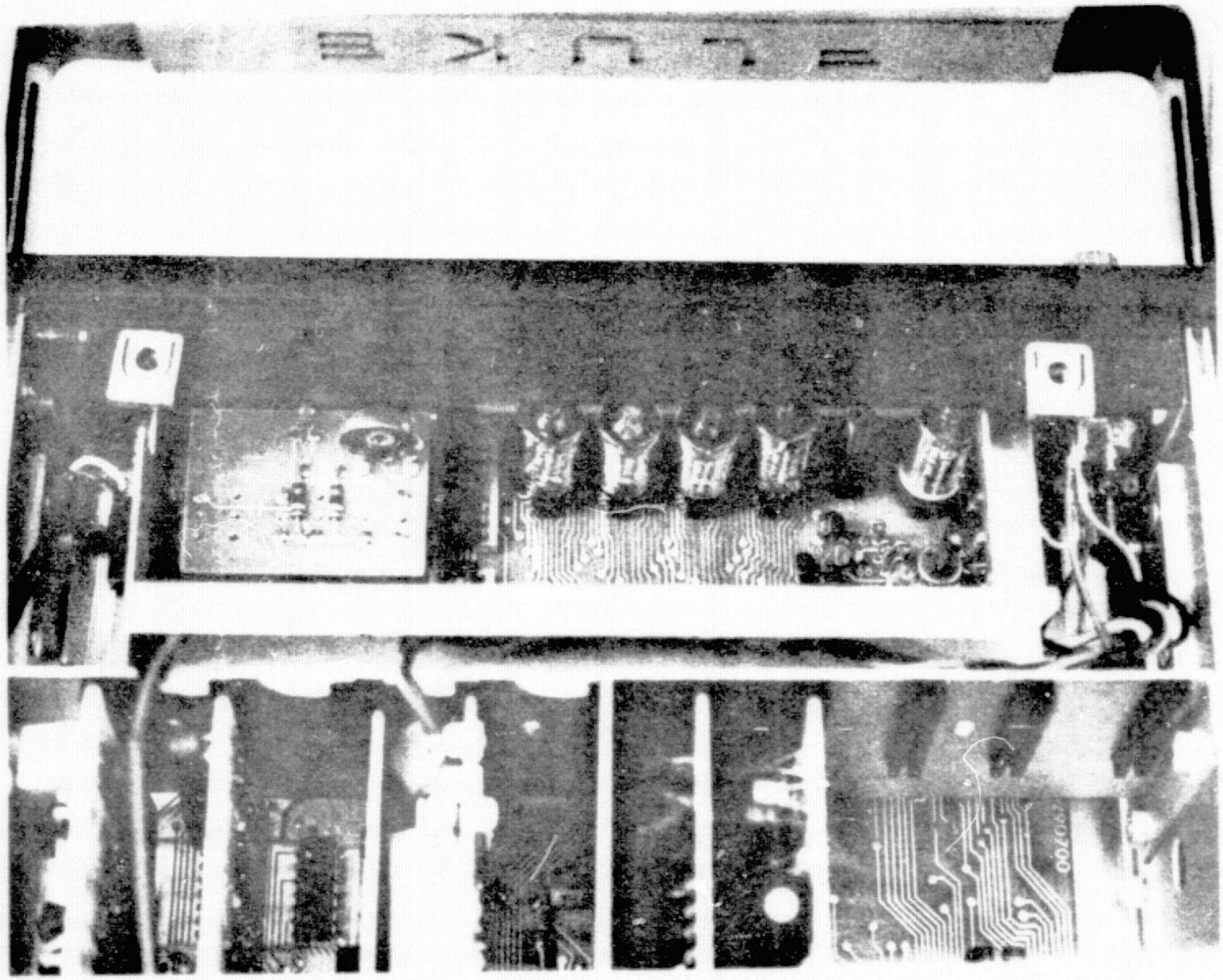

Figure 2.33-2. Nixie Tube Installation

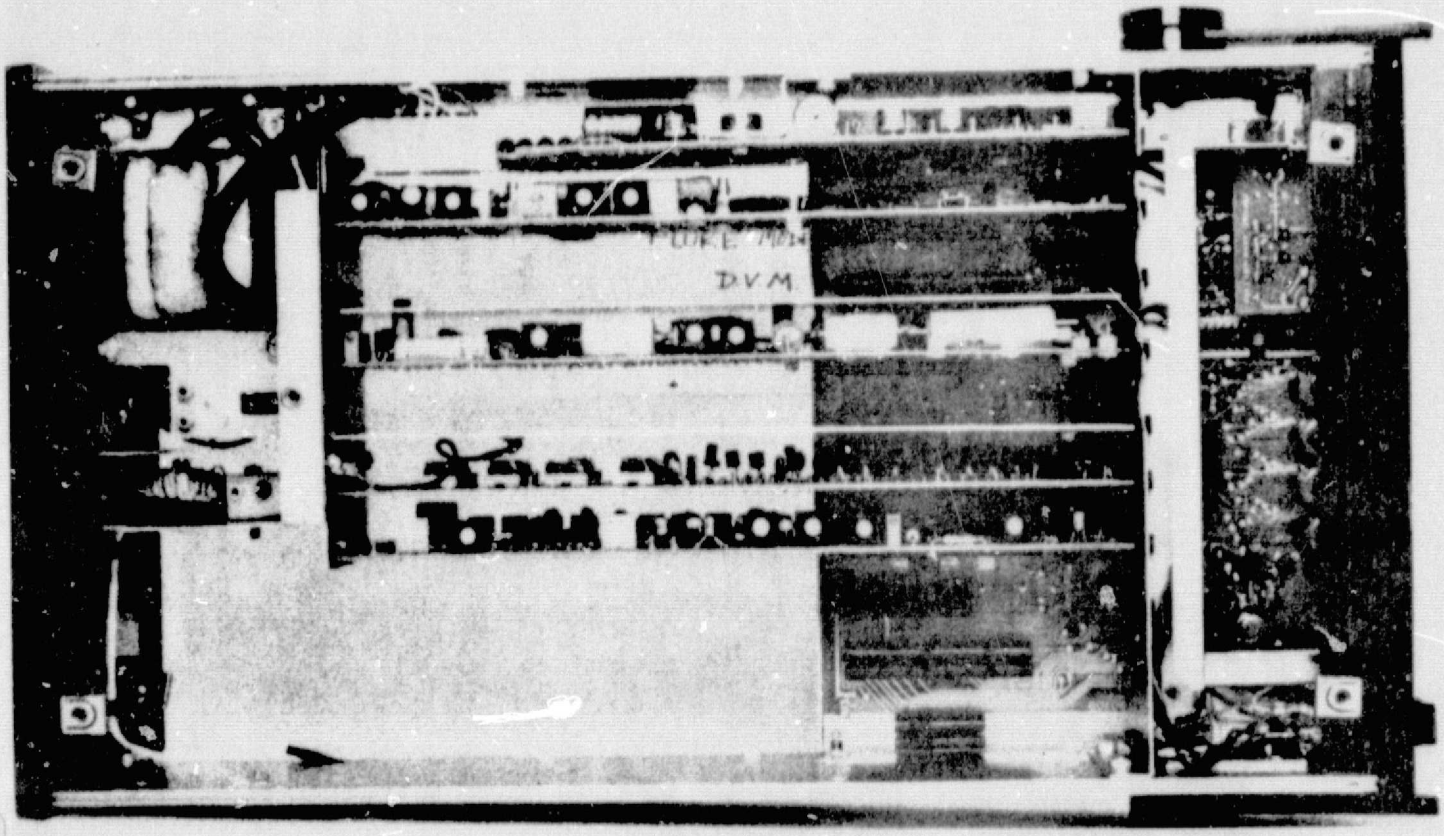

Figure 2.33-3. Voltmeter Top View

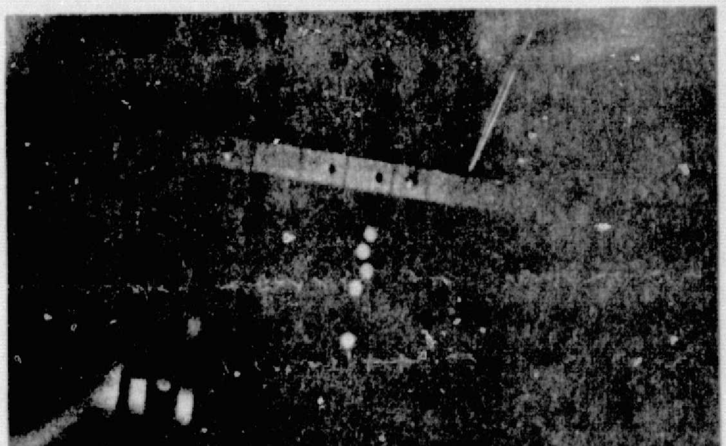

Figure 2.33-4. Slotted Guides Used For Circuit Board Retention

FLUKE MODEL 8200A
DVM

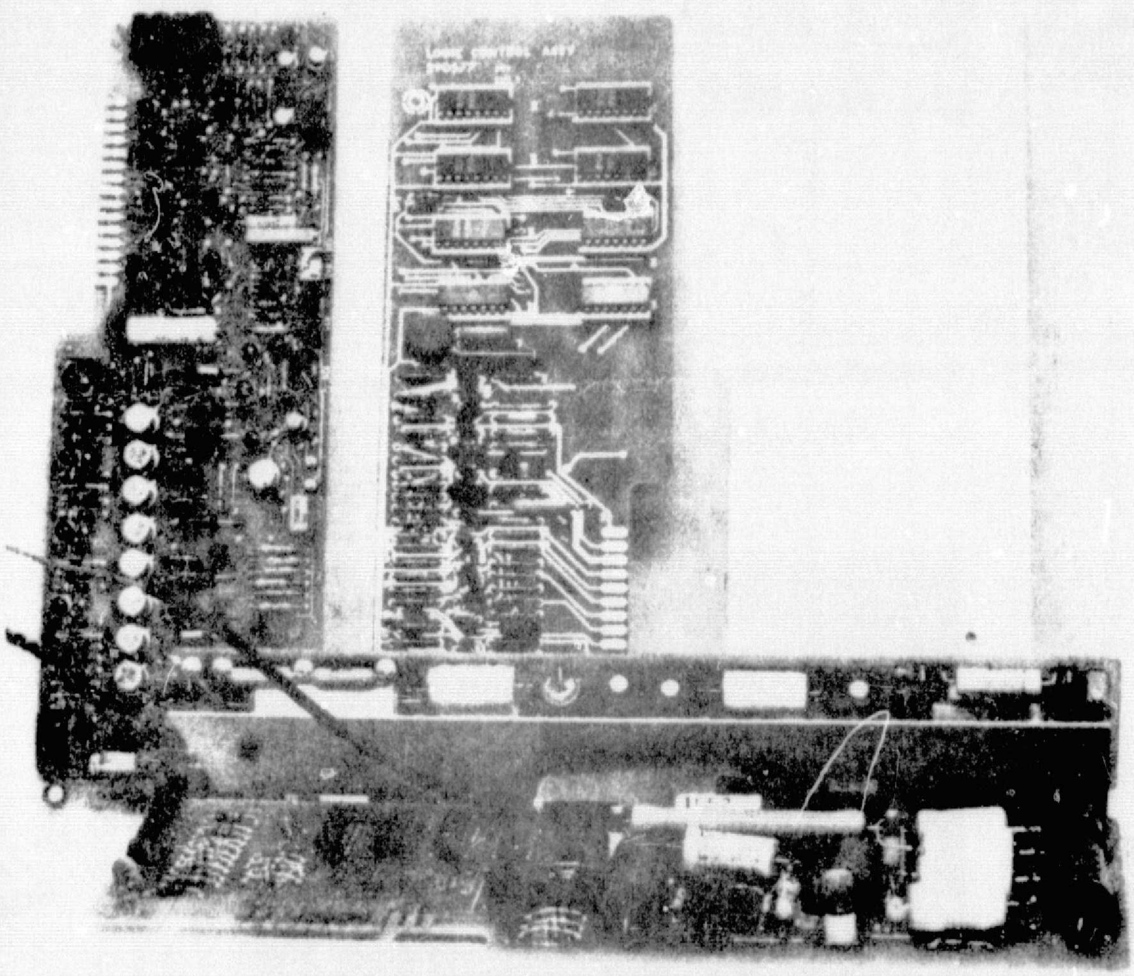

Figure 2.33-5. Circuit Board Assemblies

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	Disposition		
	Accept	Verify	Unaccept
FLAMMABILITY			
ABS plastic outer case			X
PVC insulated wiring for 34 wires			X
Plastic pushbuttons			X
Pehnolic-impregnated fiberglass printed circuit board		X	
TOXICITY			
Nixie tubes contain mercury gas for filament shock suppressant.			X
CONTAMINATION GENERATION			
Glass nixie and neon tube particles could escape unit in event of breakage.			X
Unidentified solvents used during manufacture.			X
RELIABILITY			
10,000 hr MTBF			
ATMOSPHERE			
Humidity range: -10 C to 25 C; less than 90% relative humidity	X		
25 C to 50 C; less than 80% relative humidity			
Altitude Range: Operating; to 10,000 ft (3,048 km) ≈ 10 psia	X		
Non-Operating; to 50,000 ft (15,240 km) ≈ 1.5 psia	X		
AMBIENT TEMPERATURE			
Temperature Range: Operating; -10 C to 50 C Non-Operating; -40 C to + 75 C	X		
EQUIPMENT COOLING			
Relies on natural convection in bench-mounted configuration.			X
Rack-mounted unit can be cooled by forced-air cooling from rack.	X		
Power transistors on side of unit tend to overheat. See Figure 2.33-6.			X

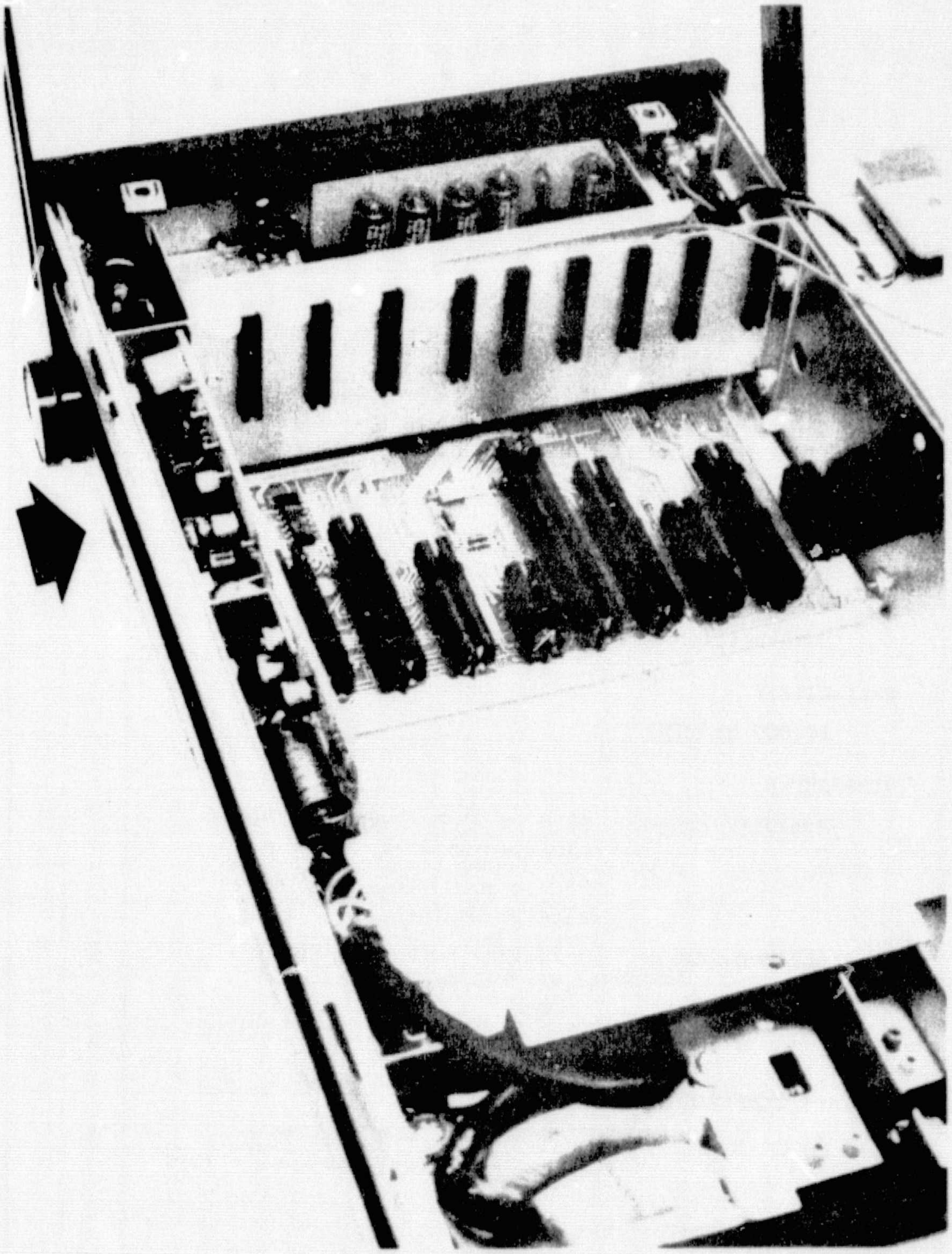

Figure 2.33-6. Hot, Side-Mounted Components

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	Disposition		
	Accept	Verify	Unaccept
OPERABILITY			
Requires probe storage when not in use.			
Protrusion protection			X

2.33.5 Modifications

Shatterables

Place screen around nixie tubes to contain shattered glass in case of tube breakage.

Protrusions and Edges

Incorporate 1/2-in. (1.28 cm) diameter guards on 19-inch rack adapter to protect unit from inadvertent bumps.

Shock, Vibration, Acceleration, Acoustic Resistance

1. Nixie tubes and neon lamps. A small, cushioned sheet metal clamp is needed to ensure that these components stay in their sockets. See Figure 2.33-7.

2. Circuit card security. Add foam rubber strips to existing clamp strips to increase clamping pressure.

3. Wires and cables. A few additional clamps and Ty-Wraps are needed to immobilize wires--various locations inside instrument.

4. Components. Conformal-coat circuit boards, except mother board. There are six boards 3 in. by 9 in. (7.6 by 22.4 cm).

5. Screws and nuts. Replace with thread-locking type.

6. Support panel indicator lights by mounting to chassis.

7. Pin knobs and pushbuttons to shaft/levers.

Materials

1. Bakeout unit for 150 hours to reduce outgassing.

2. Replace all plastic ABS and PVC with Teflon,metal or polyimide materials including knobs, case and wire insulation.

3. Replace plastic case with metal case.

4. Replace mercury-buffered nixie tubes with non-mercury tubes.

5. Conformally coat circuit boards for materials sealing and vibration support of small components.

Thermal

Rack design must allow the introduction of forced air to bottom or rear of instrument. Holes must be added to rear partition of nixie tube chamber, and to front of top cover, to allow a portion of forced air to exit past nixie area. All holes to be screened (note that only holes on top cover are presently screened. See Figure 2.33-8.

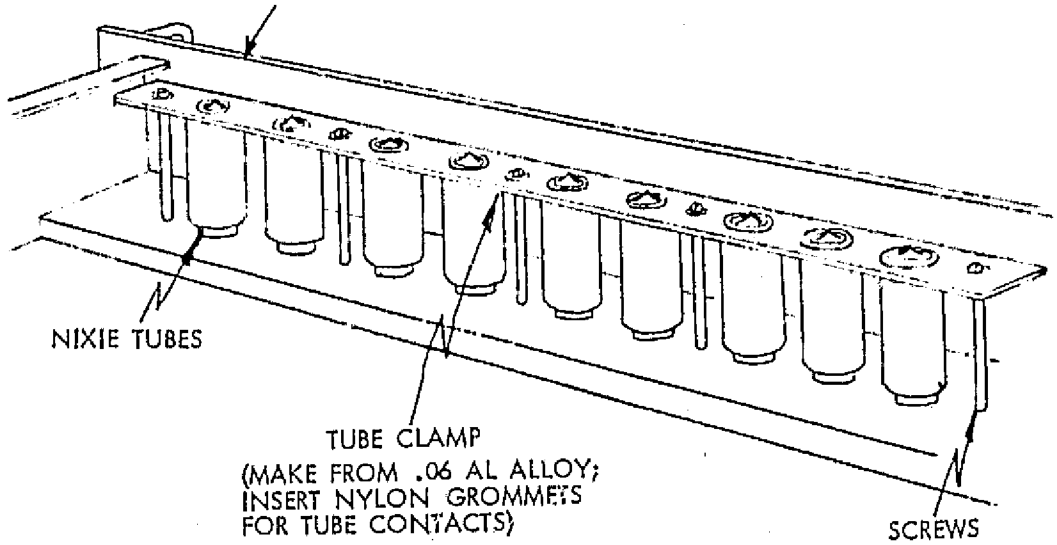

Figure 2.33-7. Securing Method - Nixie Tubes

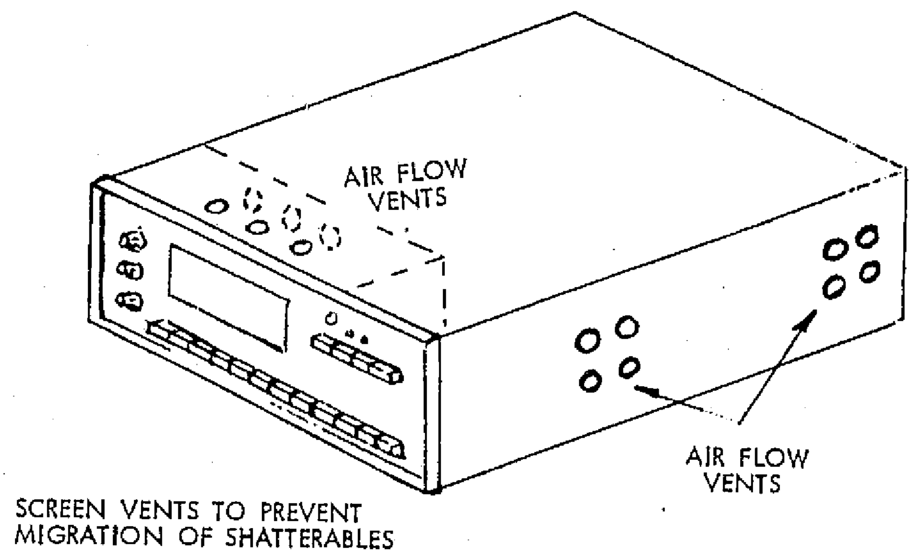

Figure 2.33-8. Thermal Control Modifications

Large air exit holes should be added on instrument side, adjacent to transformer and power transistor.

Electromagnetic Interference

Add screening around nixie tubes.

2.33.6 Cost Analysis

Modification

Basic Cost		$ 1,142
Modification Cost		
Fabrication	$ 4,652	
Engineering	12,935	
Test	2,944	
Documentation	2,160	
Program Management	1,056	
Total Modification Cost		23,747
Total Cost		$24,889

New Development

Cost	$40,000
Weight	10 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Space Station Exp. 5.22 Support Equipment

2.33.7 EC006M Modification Requirements Summary

1. Provide non-operating vacuum (only) capability (from ~1.6 psia current capability).
   a. Provide chamber and test time for acceptance and qualification.
   b. Respecify and replace 60 electronic parts for vacuum.
2. Provide connector interface for item-level testing.
   a. Add a 50-pin connector at external interface.
   b. Add a 50-wire test harness (to 16 assemblies).
   c. Patch wire 15 PCB's test signals to spare PCB pins (~3 per PCB).
   d. Add a hard-mounted signal isolation circuit board (22 discretes).

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. 1 ASSEMBLY NAME DVM - Fluke Model 8200A NEXT ASSY NO. 1363-1175-800 DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.					COST $ MAT'L	LABOR	TOTAL
		PART 1 - Specific Items Per Engineering													
		Fab. Plug (Mold)	1	3 00	1 00	10							10 00		
		Fab. Foam Seal	1	3 00		50		3 00					5 00		
		Fab. Foam Top Seal	1	1 00		25		1 80					3 00		
		Fab. Edge/Protrus, Bracket	2	2 00		20							10 00		
		Fab. Nixie Clamp	1	1 50		10							10 00		
		Fab. Custom Mount	1	50		10							5 00		
		Fab. Foam Strips for Cards	5		3 00	50							5 00		
		Install Clamps & Tie Wrap	x8		1 50	75							4 00		
		Conformal Coat 6 PCB's			8 00	25							5 00		
		Replace Nixie Tubes			1 00								30 00		
		Power Line Filter		1 00	50	25	1 00						2 50		
		Case Plastics Replaced w/Metal Must be Shielded from Existing Inner Case (New Front & Back Panels-Top & Bottom)		36 00		2 00							180 00		
		Add Holes to Bottom of Inner Case		1 00		10							6 00		
		Add Holes to Rear of Nixie Chamber		4 00		20							5 00		
		Add Holes to Top Front of Top Inner Cover		1 00		10							6 00		
		TOTAL HOURS													

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			TOTAL
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			TOTAL

Space Division Rockwell International

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MANUFACTURING COST ESTIMATE

ASSEMBLY NO. ______ ASSEMBLY NAME DVM - Fluke Model 8200A NEXT ASSY NO. ______ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	FAB	ASS'Y	INSP.	TEST	M.E.	MFG TECH	Instr Libr.	EXPD		MAT'L	LABOR	TOTAL
				LABOR HOURS									COST $		
		Drill Holes in Side of Frame for PS Vent		1 00		10							6 00		
		PART 2 - Non Specific Items Required to Perform Part 1 Operation													
		Total Disassembly w/Documentation						8 00	8 00						
		Assembly w/New or Modified Parts & Rework		6 00				6 00	14 00				3 00		
		Test & Realignment					16 00								
		Seal All Adjustments			2 00	50									
		Certified Calibration by Instrument Library								4 00					
		System Support - General				8 00		20 00			10 00		50 00		
		Replace all Hardware	50						2 00				12 50		
		150 Hour Bake Out						16 00					500 00		
		Replace all Wire w/TFE	25		5 00	3 00		6 00	6 00				7 50		
		Fab. New Push Buttons & Pin Shafts	15	15 00	1 00	1 00							375 00		
		TOTAL HOURS		86 00	22 00	18 05	17 00	56 00	34 50	4 00	10 00		1240 50		
LOT SIZE FROM	TO	RATE													
		O.H.													
		TOTAL											1240 50	3546 34	4652 84
		TOTAL													
		TOTAL													

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3. Provide connector/wire junction moisture sealing.
    a. 12 PCB (1 used for ribbon cable connection)
    b. 3 PCB type output
    c. 2 round-pin power and input connectors

4. Replace PVC as follows (delta to SEEIR modifications):
    a. 50 loose wires

5. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability, safety, interchangeability/replaceability and human factors design.**

2.33.8 Delta Modification Cost

Fabrication	$ 872	
Engineering	15,521	
Test	5,170	
Documentation	2,562	
Program Management	1,206	
Total delta modification cost		$25,331

2.33.9 Data Sources

1. 1973 Catalog - Test and Measurement Instruments, John Fluke Manufacturing Company, Inc.

2. Instruction Manual - Model 8200A Digital Voltmeter, John Fluke Manufacturing Company, Inc.

3. Visual examination of unit.

4. Telecon with J. Cunningham, John Fluke Manufacturing Company, Inc.

4. Meeting with M. Thompson, Instrument Specialists, Inc., on March 1, 1974.

2.34 MIL-SPEC VOLTMETER

Manufacturer: John Fluke Mfg. Co., Inc.
Model Number: 8125A
Cost: $1845

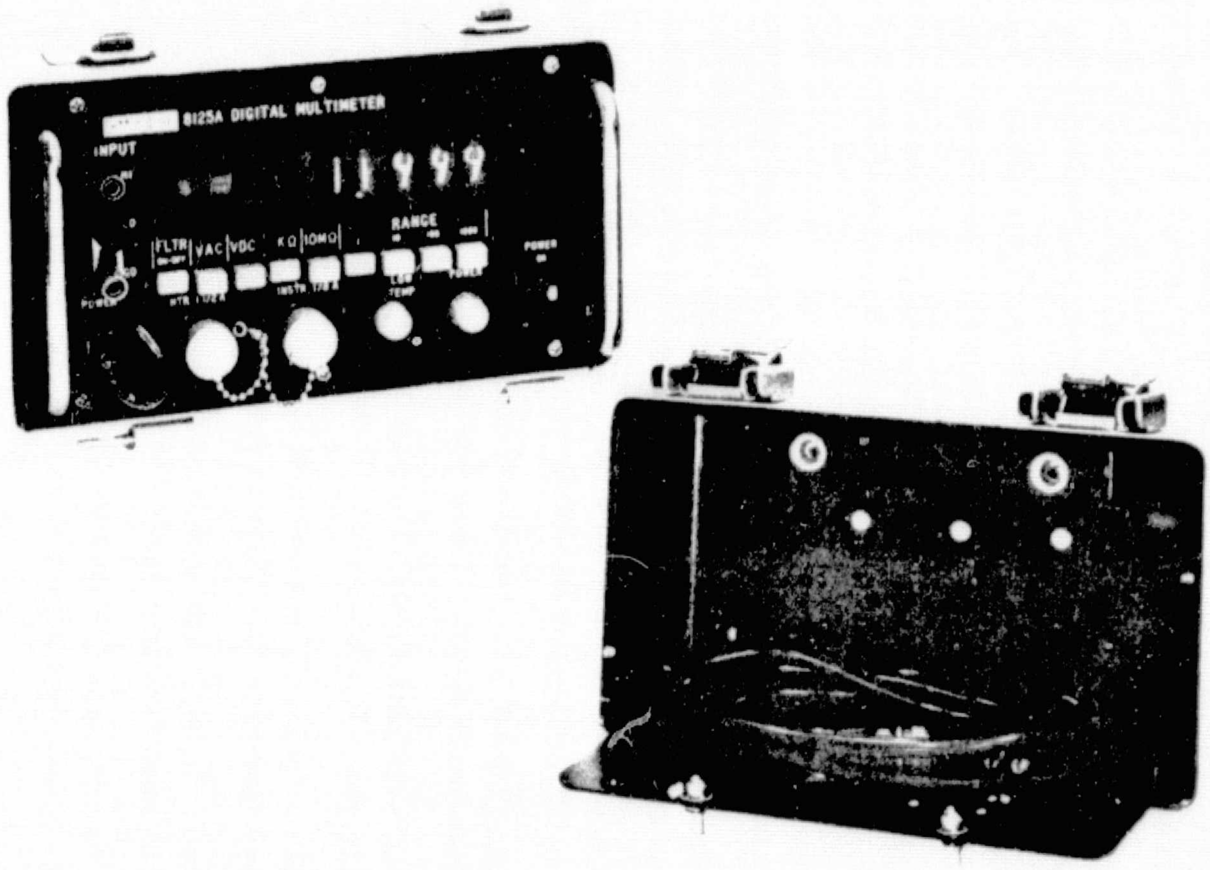

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Figure 2.34-1. Fluke Model 8125A Digital Multimeter

2.34.1 Description

The Fluke Model 8125A is a compact, rugged, truly portable militarized digital multimeter with extreme reliability and recalibration intervals as long as one year. It meets the stringent Class 2 environmental requirements (except "explosive conditions") of MIL-T-21200H when operated from 50 to 500 Hz, 115V/230V line power.

An in-line readout displays polarity, a "1" for 20-percent overrange and four full decades of digits with automatic decimal positioning. Sealed pushbutton switches select ranges and functions while a sealed toggle switch applies line power. Internal heaters automatically energize at ambient temperatures below 0 C when the instrument is line-powered. The "LOW TEMP" lamp indicates that the heaters are "ON".

All analog inputs are scaled for processing through the same operational amplifier prior to digitization in the unique, Fluke-designed, "Recirculating Remainder" analog-to-digital converter. The converter uses only one decade of BCD counter and resistive ladder network to sample the input and serially determine and display all digits. A unique capacitor register is used to hold the digits between samples. A low parts count and low instrument power consumption result from the efficient use of analog circuitry combined with the digitizing technique.

2.34.2 Performance Characteristics

DC Volts

Ranges	$\pm$1V, $\pm$10V, $\pm$100V and $\pm$1000V, 20% overrange all ranges
Resolution	0.01% of range (100 uv on 1V range maximum)
Accuracy	
90 days, 20 C to 30 C	$\pm$(0.01% of input + 0.01% of range)
6 months, 15 C to 35 C	$\pm$(0.01% of input + 0.02% of range)
1 year, 15 C to 35 C	$\pm$(0.02% of input + 0.02% of range)
Temperature Coefficient	$\pm$(0.0015% of input + 0.001% of range)/^{o}C
DC Input Resistance	Constant 10 megohms on all ranges
Filter	Switch selected 2-pole, linear phase active filter
Settling Time to Rated Accuracy	
Filter "out"	0.25 seconds
Filter "in"	1.2 seconds

Rejection

	DC	INTERFERENCE FREQUENCY 60 Hz FILTER IN	60 Hz FILTER OUT	50 Hz FILTER IN	50 Hz FILTER OUT
COMMON MODE (1 KΩ in Low Lead)	120 db	120 db	100 db	120 db	100 db
NORMAL MODE	------	60 db	20 db	47 db	9 db

Polarity: Automatic, instantaneous selection and display

Overload: ±1200V dc or ±1700V peak ac can be applied continuously to any range without damage.

AC Volts

Ranges: 1V, 10V, 100V and 1000V, 20% overrange on all ranges
Resolution: 0.01% of range (100 uv on 1V range maximum)

Accuracy:	50 Hz - 10 kHz	30-50 Hz and 10-20 kHz
90 days, 15 C to 35 C	±(0.2% of input + 0.05% of range)	±(0.5% of input + 0.1% of range)
6 months, 15 C to 35 C	±(0.2% of input + 0.08% of range)	±(0.5% of input + 0.1% of range)
1 year, 15 C to 35 C	±(0.2% of input + 0.15% of range)	±(0.5% of input + 0.15% of range)

Input Impedance: 1 megohm shunted by <30 pf.

Settling Time to Rated Accuracy: 2.8 seconds

Maximum DC Normal Mode Voltage: ±1200V dc NOTE: The sum of dc normal mode voltage and peak ac voltage must not exceed ±1700V.

Overload: ±1200V dc or ±1700V peak ac from 30 Hz to 20 kHz can be applied continuously to any range without damage.

Resistance

Ranges: 1K, 10K, 100K, 1000K and 10M, 20% overrange on all ranges
Resolution: 0.01% of range (0.1 ohm on 1K range maximum)

Accuracy:	1K - 1000K	10M
90 days, 20 C to 30 C	±(0.02% of input + 0.01% of range)	±(0.05% of input + 0.01% of range)
6 months, 15 C to 35 C	±(0.02% of input + 0.02% of range)	±(0.07% of input + 0.02% of range)
1 year, 15 C to 35 C	±(0.02% of input + 0.03% of range)	±(0.07% of input + 0.03% of range)

Configuration: Two-terminal constant current (+9V across open terminals)

Current In R Measured: 0.7 ma on the 1K range, decreasing by an order of magnitude per range to 70 na. on the 10 megohm range.

Settling Time to Rated Accuracy:	1K - 1000K	10M
Filter Out	0.25 sec	2.8 sec
Filter In	1.8 sec	10.0 sec

Overload

1K Range	130V rms may be applied continuously without damage.
1K - 10M Range	230V rms may be applied continuously without damage

General

Selection	Manual via mechaniclly interlocked pushbuttons
Display	Four-decade neon in-line readout with polarity neon for dc volts, and fifth digit for 20% overrange. Automatic decimal location.
Sample Rate	3 samples per second

Maximum Inputs:

HI to LO	See "Overload" specification by function
LO to GUARD	100V dc or peak ac
GUARD to CHASSIS	1200V dc or 230V rms at 60 Hz

Temperature Coefficients (Apply outside of temperature ranges of "accuracy" specifications. Use temperature coefficient for 0 C when temperature is between 0 C and -40 C):

dc $\pm$(0.0015% of input + 0.001% of range)/^{o}C
ac $\pm$(0.015% of input + 0.005% of range)/^{o}C
k ohms $\pm$(0.0015% of input + 0.001% of range)/^{o}C
10M ohms $\pm$(0.008% of input + 0.001% of range)/^{o}C

2.34.3 Physical Characteristics

Weight: 20 lb (9.08 kg) without batteries

Size: Linear dimensions, 20.19 in. long (with cover on) x 6.63 in. high x 9.84 in. wide (51.3 x 16.8 x 25.0 cm)

2.34.4 Suitability Analysis

	Disposition		
	Accept	Verify	Unaccept
CONSTRUCTION. A MIL combination case completely encloses the instrument. Its detachable cover protects the front panel while serving as a storage space for accessories, test leads and the line cord. A recessed carrying handle is attached to the cover's exterior.			
Unit is not built for 19-inch rack installation. Alternative is to store and use in portable, battery-powered configuration.			X
MATERIALS			
Unit is metallic Glass viewing window Typical electronic components Plastic knobs			
SHOCK, VIBRATION, ACCELERATION AND ACOUSTIC ENVIRONMENT			
Spec. Withstands 18 impact shocks of 20G--3 shocks in opposite direction along each of the mutually perpendicular axes. Withstands continuous vibration along each of the mutually perpendicular axes as follows:	X		

Frequency Range	Double Amplitude
5 to 15	0.06 inch
15 to 25	0.04 inch
25 to 55	0.02 inch

	Accept	Verify	Unaccept
Visual Exam.			X
Nixie tube supported only in base connector			X
Larger circuit board components require positive retention			X
12 internal adjustable pots are not positively retained			X
Circuit boards require positive retention to prevent oil-canning.			X

	Disposition		
	Accept	Verify	Unaccept
ELECTRICAL POWER			
3 watts during 8 hours of continuous operation from rechargeable nickel-cadmium batteries	X		
8 watts from 115/230 volt ac ±10%, 50 to 500 Hz			
An optional battery pack may be installed in the field or factory. A meter along side of the digit readout indicates the state of battery charge. The battery is automatically charged when the 8125A is operated from line power. Disconnecting the line cord enables battery operation when the ambient temperature is greater than 0 C. Thermostat interlocks provide for line operation only with energized heaters from 0 C to -40 C.			
DATA MANAGEMENT COMPATIBILITY. Visual display only. No signal outputs available to interface with data management. Verify need before modification.		X	
EMI SUSCEPTIBILITY AND RADIATION. Meets requirements of MIL-STD 461A, Class B1, Notice 3. Uses common mode rejection circuits.	X		
NOISE GENERATION. No generation.	X		
FLAMMABILITY			
Hermetically sealed	X		
Plastic knobs and pushbuttons			X
TOXICITY. Hermetically sealed (nixie tubes may contain mercury traces).	X		
CONTAMINATION GENERATION. Glass nixie tubes.			X
CONTAMINATION SUSCEPTIBILITY	X		
Sand and Dust: Meets para. 3.2.19.6 of MIL-T-21200H			
Salt Atmosphere: Meets para. 3.2.19.7 of MIL-T-21200H			
RELIABILITY			
10,000 hr MTBF	X		

	Disposition		
	Accept	Verify	Unaccept
ATMOSPHERE			
Pressure: Operating, 10,000 ft Non-Operating, 50,000 ft	X		
Humidity: Operating, 0 to 100% RH	X		
Dessicant in case to maintain low humidity internally			
AMBIENT TEMPERATURES			
Storage: -62 C to + 85 C (-40 C to +60 C with batteries installed)	X		
Operating: -40 C to +55 C (line operation only below 0 C and intermittent operation to +71 C)	X		
EQUIPMENT COOLING			
3-watt power dissipation below threshold requiring special cooling provisions.	X		
Heaters assure internal temperature remains above 0 C on line operation (capability not necessary for Spacelab operations)			
ZERO-G EFFECTS. No gravity-dependent functions	X		
OPERABILITY. Line power is applied through the front panel of the instrument. All fuses and indicator lamps are front-panel mounted. A concealed slide switch at the rear of the instrument's chassis is used for selection of 115v or 230v ac line power.			
Handles provide protrusion protection; however, not to 1/2-inch radius. Verify if adequate. Probe must be stored when unit is not in use.		X	

2.34.5 Modifications

Shatterables

Replace readout window with transparent Lexan.

9-G Mounting

Remove cover, hinges, latches, batteries, and heater circuits. Fabricate and install rack mount flanges per Figure 2.34-2.

Shock and Vibration

1. Secure nixie tubes with special clamp; see Figure 2.34-3, which illustrates Datatron time code generator modification.
2. Clip six large components to circuit board per paragraph 4.0 of Design Guidelines.
3. Secure circuit board per paragraph 11.0 of Design Guidelines.

Materials Usage

Replace plastic knobs on front of case.

2.34.6 Cost Analysis

Modification

Basic Cost		$2,118
Modification Cost		
Fabrication	$1,535	
Engineering	5,778	
Test	2,944	
Documentation	2,160	
Program Management	621	
Total Modification Cost		13,038
Total Cost		$15,156

New Development

Cost	$40,000
Weight	10 pounds
Complexity	1.00
State-of-the-Art Factor	2
Data Source	Space Station Exp. 5.22 Support Equipment

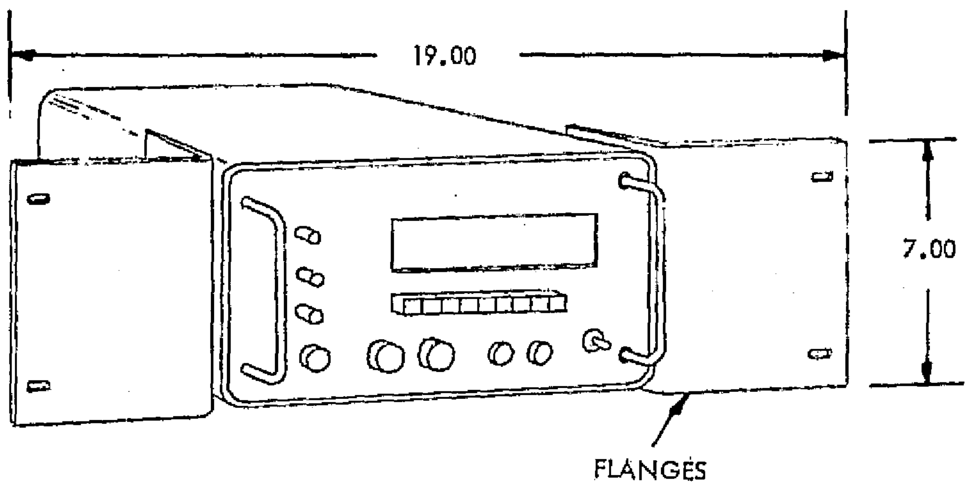

Figure 2.34-2. Rack-Mounting Configuration Digital Multimeter (Militarized)

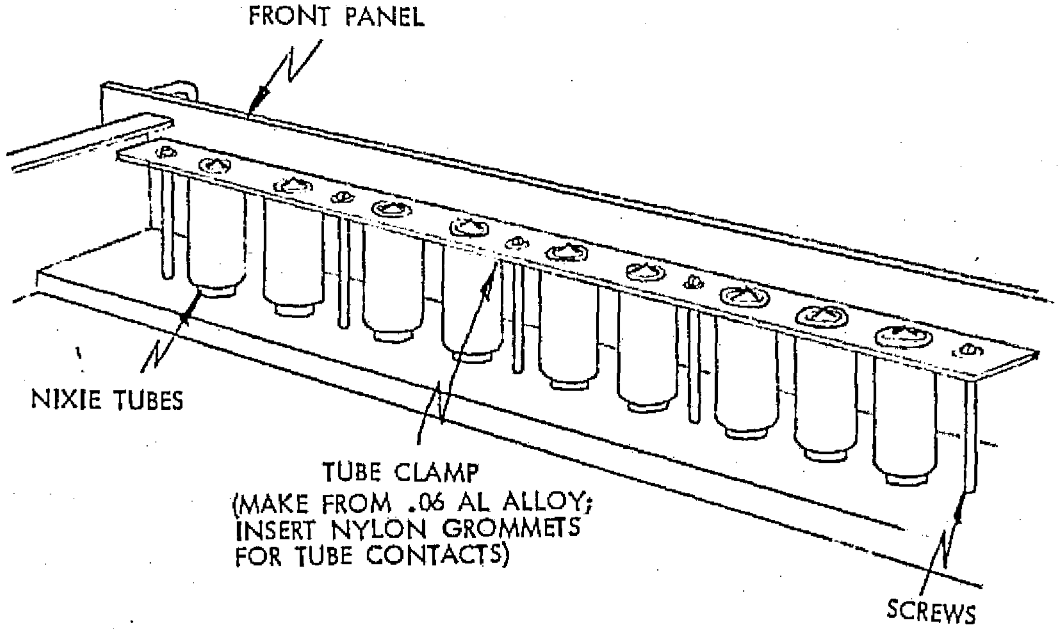

Figure 2.34-3. Securing Method - Nixie Tubes

MANUFACTURING COST ESTIMATE

ASSEMBLY NO. Model 8125A ASSEMBLY NAME Digital Multimeter - Fluke NEXT ASSY NO. ________ DATE / /

ITEM	PART NO.	PART DESCRIPTION	QTY	LABOR HOURS FAB	ASS'Y	INSP.	TEST	M.E.	EXPD	COST $ MAT'L	LABOR	TOTAL
		Fab. Lexan Window		1 00		10				5 00		
		Remove Cover, Hinges, Latches Batteries & Heater Circuits			3 00							
		Fab. & Install Rack Mnt. Flange	2	2 00		20				5 00		
		Fab. Tube Clamp		1 00	25	10				5 00		
		Fab. Grommets		4 00		20				3 00		
		Install Clamps	6				60			1 50		
		Secure PCB	1	1 00	40	10				1 00		
		Conformal Coat	1		1 25	20				3 00		
		Test & Calibrate & Support				15 00	40 00	20 00	10 00			
		TOTAL HOURS		14 00	11 40	18 40	40 60	38 00	10 00	536 50		
LOT SIZE FROM	TO	RATE O.H.										
		TOTAL								23 50	1511 05	1534 55
		TOTAL										
		TOTAL										

Beckman INSTRUMENTS, INC.

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SD 74-SA-0047-3

Space Division Rockwell International

2.34.7 EC006M Delta Modification Requirements Summary

1. Provide non-operating vacuum (only) capability (from current 1.6 psia capability):

   a. Provide chamber and test time for acceptance and qualification.

   b. Respecify and replace 35 electronic parts.

2. **Provide systems engineering, test, documentation and coordination efforts to assure acceptable materials usage/protection, reliability, maintainability,** safety, **interchangeability/replaceability and human** factors design.

3. Replace PVC as follows (delta to SEEIR modifications):

   a. 10 loose wires

4. Human factors modifications:

   a. Redesign to make the large circuit board easily replaceable.

2.34.8 Delta Modification Cost

Fabrication	$ 133
Engineering	11,463
Test	4,582
Documentation	2,562
Program Management	937

Total delta modification cost 19,677

2.34.9 Data Sources

1. 1973 Catalog, Test and Measurement Instruments, John Fluke Manufacturing Company, Inc.

2. Instruction Manual - Model 8125A, Digital Multimeter, John Fluke Manufacturing Company, Inc., May 1971.

3. Telecon with J. Cunningham, John Fluke Manufacturing Company, Inc.

4. Meeting with M. Thompson, Instrument Specialists, Inc., March 1, 1974.

3.0 SPECIFICATION TRADEOFFS

Tradeoffs of specification requirements were performed to determine the benefits or disadvantages resulting if NASA specifications were changed to accommodate commercial equipment. This section presents three tradeoffs of alternative specification requirements. Additionally, an analysis of the impact of operating the experiment equipment on 28 vdc power rather than 115 vac is presented.

3.1 CANDIDATE TRADEOFF IDENTIFICATION

Candidate tradeoffs were identified by comparing unmodified equipment characteristics to specified requirements and reviewing the recommendations of the suitability analysis and the comparison of the NASA preliminary equipment specification (EC006M00000A) with the Spacelab/Experiment Equipment Interface Requirements specifications. The characteristics of the unmodified equipment and the recommendations of the suitability analyses are shown in Table 3-1. The specification comparison is discussed in Section 4.0 of Volume II.

3.1.1 Unmodified Equipment Characteristics

Power requirements of the selected equipment are generally compatible with Spacelab provisions although total power demand may be high when the aggregate requirements for all equipment are considered. Most of the equipment items use 115 vac, 60-cycle power. Two units are compatible with the primary power form of the Spacelab (28 vdc). The tightest regulation requirement is ± 5 percent, with many units capable of accepting voltage variances greater than ± 10 percent. Power dissipation for many units exceeds 200 watts. If many units require these high power levels, the available Spacelab power budget for experiment equipment will be exceeded.

Approaches to reducing power demand requirements include sequencing equipment operation to be compatible with the available power budget, or modifying the equipment to consume less power. Operational sequencing requires a system analysis of an entire Spacelab payload which is out of the scope of this study. Specific equipment items with high-power demands were modified during the study. For example, the gas chromatograph heater requirement was reduced from 750 watts to 250 watts by reducing the airflow rate through the sample chamber. A third alternative is to make this equipment compatible with the 28 vdc primary power source and eliminating the power supply section of each item where much of the power is dissipated. An analysis of the impact of such an equipment modification is presented in Section 3.5.

Data output requirements vary considerably among equipment items. The incompatibilities were generally resolved by placing buffer amplifiers between the units and the data management subsystem. Also, the remote acquisition units (RAU's) proposed by the Spacelab program to interface between the equipment and the data management subsystem should further reduce these incompatibilities.

Table 3-1. Unmodified Equipment Characteristics and Suitability Analysis Recommendations

			UNMODIFIED CHARACTERISTICS									MODIFICATIONS REQUIRED										
			POWER				COOLING														
TYPE	MANUFACTURER	MODEL NO.	VOLTAGE	FREQUENCY - CPS	MAX POWER (AVG) - WATTS	DATA OUTPUT	(5) NATURAL CONVECTION	INTERNAL FAN	PORTED FOR FORCED AIR	WATER COOLING REQUIRED	VIBRATION PROTECTION	ADDITIONAL COOLING	(6) REPLACE MATERIALS (K,W,O)	BAKEOUT [illegible]	(7) [illegible] PROTECTION	(8) EMI (S,G,I/O)	REPLACE/CONTAIN SHATTERABLES	(9) PROTECTION [illegible]	FUNCTIONAL OPERATION REDESIGN	NOISE	REMARKS
TAPE RECORDER	AMPEX	M700	26 ± 9%	DC	175	40 dB GAIN	X(C)				X		*	X				X			
	HONEYWELL	5600	117 ± 9%	50/60/400	275	14 DATA CHANNELS AND 2 VOICE CHANNELS		X			X		K,W	X		G		X			
COMPUTER	DIGITAL EQUIPMENT	PDP-8/E	117 ± 15%	50/60	450	DATA TRANSFER OR VISUAL		X			X		K,W	X				X		X	
KEYBOARD/DISPLAY/TERMINAL	RESEARCH, INC.	3311?N	117 ± 6%	60	42	ALPHANUMERIC DISPLAY	X				X	X	K,W	X	X	S,G,I/O	X	X			
BLOOD CELL COUNTER	COULTER ELECTRONICS	FN	112 ± 20%	50/60	500 EST	DIGITAL DISPLAY	X				X	X	K,W,O	X	X		X	X	X (SEVERE)		NIXIES
TIMER	DATAPRON	3150	117 ± 10%	50/60/400	35	0 - 5 VDC	X		X		X		K,W,O	X			X	X			NIXIES
	TENNELEC	TC 545/214/909	117 ± 12%	60	75 EST	0 - 6 VDC	X		X		X		K	X				X			(4) TTL WIRING
SPECTROPHOTOMETER	BECKMAN	24	115 ± 12%	50/60	230	DIGITAL DISPLAY	X	X			X	X	K,W,O	X			X	X	X		(3) NIXIES
RECEIVER	SINGER	NM 37/57	115 ± 9%	50/60/400	30	VISUAL DISPLAY	X(C)				X		K	X		G,I/O	X	X			
TRANSCEIVER/TRANSMITTER	AHG	W1900	113 ± 10%	400	100	10 Hz - 12 MHz		X					K	X				X			
	COLLINS RADIO	618M-2	26 ± 15%	DC	200	300 - 3000 Hz 6 dB MAX VARIATION	X(C)						K	X				X			
AMPLIFIER - 16 CHANNEL	NEFF	126	115 ± 9%	50/60/400	500	± 10 VDC AT ± 10 MILLIAMPS	X		X		X		*	X	X			X			
MULTICHANNEL ANALYZER	NUCLEAR DATA	ND100	115 ± 5%	50/60	200	ALPHANUMERIC DISPLAY		X			X		K,W	X	X		X	X		X	
SPECTRUM ANALYZER	HEWLETT-PACKARD	141T/8552/8555/8445	117 ± 8%	50/60/400	295	CRT DISPLAY		X			X		K,W	X		G	X	X		X	
WAVE ANALYZER	SINGER	SSB 50-1L	117 ± 15%	50/60/400	50	METER 0 - 1V	X(C)				X		K	X			X	X			
FREQUENCY SYNTHESIZER	FLUKE	645A	115 ± 10%	50/60/400	125	0.2 TO 1.0 VRMS 1.0 VRMS ± 1 dB INTO 50 Ω	X(C)					X	*	X		I/O		X			COOLING MOD IS EXTERNAL
LAMP ASSEMBLY	SYLVANIA	944	115 ± 5%	60	600	HIGH INTENSITY BEAM OF INFRARED LIGHT				X	X		*	X				X			
GAS CHROMATOGRAPH (ANALYZER AND PROGRAMMER)	BECKMAN	6700	117 ± 9%	50/60	750	VISUAL DISPLAY	X_A(C)	X_P			X		K,W_P,O_P	X	X	G_A		X	X		
MICROSCOPE	AMERICAN OPTICAL	XH20TG-OW	115 ± 15%	60	125	VISUAL	X				X	X	O	*	X	S	X		X		* BAKEOUT NOT REQD. WITH HEAT GUARD MODIFICATION. * STORED UNTIL USED.
STRIP CHART RECORDER	HONEYWELL	1858	117 ± 9%	50/60/400	306	18 DATA CHANNELS ON MOVING PHOTOSENSITIVE PAPER	X				X	X	K,W	X			X	X	X		
VOLT/OHM METER	FLUKE	8200A	115 ± 10%	50/60/400	25	VISUAL DISPLAY	X				X	X	K,W,O	X			X	X			NIXIES
	FLUKE	8125A	115 ± 10%	50/60/400	3	VISUAL DISPLAY	X(C)				X		O	X			X	X			NIXIES
OSCILLOSCOPE	TEKTRONIX	485	113 ± 20%	50/60/400	60	VISUAL DISPLAY		X			X		K,W	X		G	X	X			
	HEWLETT-PACKARD	AN/USM-281A	115 ± 10%	50/60/400	125	VISUAL DISPLAY	X				X	X	-	X			X	X			
ELECTROPHORESIS APPARATUS	BECKMAN	RM	115 ± 9%	50/60	100	VISUAL		X			X		K,W	X			X	X	X		(2)
FURNACE	ASTRO	1000A	220 ± 5%	60	8 KVA	NA				X	X		-	-	X	S		X			(?)
DEWAR	CRYOGENIC ASSOCIATES	IR-90	-	-	-	NA	NA						O	-			X		X (LEVEL)		STORED UNTIL USED
POWER SUPPLY	SORENSON DIVISION OF RAYTHEON	SRL 40-12	115 ± 9%	50/60	1,500	0 - 40 VDC	X				X	X	K,W,O	X				X			
	POWER DESIGNS	ARC 320-3	117 ± 15%	50/60	30?	± 12 / ± 24 VDC	X		X		X		-	X				X			
CENTRIFUGE	CLAY ADAMS	CT 1004	115 ± 5%	60	306	VISUAL	X				X		W,O	X	X			X			
REFRIGERATOR/FREEZER	REVCO	ULT-185A	220 ± 5%	60	336	NA		X			X		W,O	X	X	S		X	X (LEVEL)	X	
PARTICLE COUNTER ASSEMBLY	[illegible]	401/TC611/420/410	117 ± 11%	60	100 EST	0 - 5 V	X		X		X		K	X			X	X			(4)
MICROTOME	AMERICAN OPTICAL	820	-	-	-	NA					X		O	-	X			X			
pH METER	BECKMAN	PHASAR I	115 ± 5%	50/60	3	VISUAL DISPLAY	X				X		K,W,O	X			X	X	X		

NOTES:
(1) SPECIAL POWER SUPPLY AND COOLING UNIT NEEDS ADDITIONAL MODS.
(2) FUNCTIONAL OPERATION REDESIGN IS TO MAKE RE-CALIBRATION EASIER. FAN IS PRIMARILY FOR LAMP COOLING.
(3) INCLUDES CELL, DENSITOMETER, POWER SUPPLY.
(4) INCLUDES MAINFRAME FOR 19 INCH RACK W/INTERCONNECTOR WIRING.
(5) "(C)" MEANS TOTALLY ENCLOSED CASE WITH INTERNAL CONDUCTION TO CASE, THEN CONVECTION (VENTED TO ATMOSPHERE DUE TO MINOR LEAKAGES IN CASE FIT).
(6) "K,W,O" MEANS CONTROL KNOBS, WIRING HARNESS, OTHER UNIDENTIFIED/TOXIC/FLAMMABLE MATERIALS.
(7) DISINTEGRATION/LOSS OF PARTS POTENTIAL. - - - DOES NOT COVER ITEM MOUNTING.
(8) INCLUDES SHIELDING (S), CHASSIS - SIGNAL RETURN ISOLATION (G), INPUT/OUTPUT (I/O) ISOLATION/VOLTAGE LEVEL/IMPEDANCE.
(9) DOES NOT CONSIDER EXTERNAL PROTECTION THAT MAY BE FURNISHED BY RACKS, LOCATION, ETC.

Most units have adequate cooling provisions. Units that utilized convection as a basic cooling mode were easily modified for forced-air cooling. Other units such as airborne units were designed to operate in low-pressure environments by using conduction as a primary heat dissipation mode. An analysis of approaches to support water-cooled units appears appropriate since Spacelab is not providing a liquid-cooling interface to experiment equipment. Because only two items are affected, the tradeoff was not performed in this study. Examination is recommended in any succeeding study.

3.1.2 Suitability Analysis Recommendations

The areas requiring most of the equipment modifications are vibration integrity, material control, confinement of shatterables, and protection from protrusions and sharp edges. The remaining areas did not display as high a modification frequency and therefore did not receive the same priority for tradeoff analysis.

Almost every unit analyzed required some modification to withstand the vibration environment. The modifications recommended appear adequate, however, location of vibration peaks, harmonic amplification, and other secondary effects could not be predicted. A test program has been recommended to assess the vibration integrity of selected equipment items. Another avenue available to reduce the effects of vibration is to reduce the environment induced upon the equipment. An analysis of vibration isolation approaches is presented in Section 3.2.

Every item analyzed, with the exception of one, required a material change. Plastics are generally used throughout commercial equipment. Polyvinyl chloride is a commonly used wire insulation and is generally unacceptable. Section 3.3 discusses the benefits of relaxing the tight NASA material control requirements to the level defined by the Spacelab/Experiment Equipment Interface Requirements (SEEIR) specification. Alternative approaches to further relaxing this specification are also discussed.

Modifications for physical protection of the crew are required by most equipment items, but the cost of such modifications is low. Relaxed specifications for shatterable containment and protrusion protection would decrease the safety integrity of the Spacelab and therefore were not considered as possible tradeoff candidates.

3.1.3 Specification Comparison

Table 3-2 identifies the potential specification changes that could be performed to make the NASA specification compatible with the use of commercial equipment. All of these requirements are potential tradeoff candidates. The corrosion and fungus requirement was selected for tradeoff because it represents a requirement class, i.e., degradation prevention requirements. Also, relaxation of other requirements may be more easily proven. Section 3.4 presents the assessment of the impact of relaxed corrosion and fungus control requirements.

Table 3-2. Potential Specification Changes Indicated by Specification Comparison

Eliminate degradation-type requirements (fungus, corrosion)
Relax nonoperating temperature and vacuum criteria
Eliminate built-in test connectors
Relax safety interconnects
Eliminate interchangeability
Eliminate human engineering specification
Eliminate connector sealing
Addition of rules-of-thumb design guide

Nonoperating temperature and vacuum specifications could be relaxed by assuring that the equipment is not exposed to extreme environments. The Orbiter is currently being designed for a minimum internal pressure of 8.0 psia. The Spacelab only quotes a nominal pressure of 14.7 psia. Commercial units are transported by commercial aircraft in pressurized cargo bays when necessary, eliminating transport prior to space flight as a design driver. It can be concluded that vacuum is no longer a necessary design requirement. If the equipment is exposed to a vacuum in space, the cause of the vacuum probably caused so much damage to the Spacelab that successful operation of the equipment subsequent to such exposure would not be required. Although no tradeoff was performed, consideration of an 8.0 psia minimum pressure should be made when this requirement is finalized. Similar logic could be applied to the temperature extremes defined.

Built-in test connectors and safety interconnects can also be eliminated since this equipment will be maintained on the ground by qualified instrumentation technicians. No reason has been identified to assume that the maintenance procedures followed in most laboratories and industrial facilities would not be adequate for the Spacelab equipment. If a more densely packaged aerospace-type equipment design were adopted for the test equipment, such control would be justified.

Interchangeability is provided by the equipment manufacturer on all replacement parts. Therefore, for commercial equipment this becomes an academic requirement. Configuration control has meaning only for custom-built equipment.

It may be necessary to enforce the human engineering specification on a few units although it seems improbable. Since all equipment analyzed is used successfully in laboratories and industrial facilities, human engineering shortcomings are either overcome or the marketplace eliminates the unit. (If the unit cannot be used, it does not sell.) Therefore, the equipment may not meet a specified requirement, but its use in the field proves that it can be successfully operated.

Rules of thumb for most specifications would provide laymen interpretations of the requirements that would be useful to most principal investigators. An effort to produce such rules of thumb was considered out of scope, but is recommended if a new study is undertaken.

3.2 CAM EQUIPMENT RACK VIBRATION ISOLATION

3.2.1 Objective

This section presents an evaluation of potential cost savings derived from improving vibration isolation between CAM equipment and the Spacelab.

The suitability analysis determined that almost all items would require modifications to meet the ERNO Spacelab vibration specifications used in the SEEIR baseline document. Sixty to 80 percent of the total CAM modification costs apply to vibration modifications. While the evaluations show that the modifications are highly cost-effective compared to the cost of custom equipment, these modifications could be significantly reduced if the items were more effectively isolated from Spacelab vibration. Therefore, it is appropriate to investigate the feasibility of additional isolation and to evaluate the costs of alternative means of accomplishing this.

This evaluation is preliminary; more detailed studies are warranted when new Spacelab data are developed and when the vibration capabilities of the CAM equipment are better understood. The latter need is underscored by the fact that manufacturers' vibration data were identified for only one-third of the 34 equipment items evaluated. Further, most of these (9) are specified for operating conditions only, or both operating and non-operating conditions. Since operation is the limiting factor in passing the specified tests, presumably the equipment items could withstand somewhat greater levels of vibration when not operating.

The study is directed primarily at standard rack-mounted equipment because 25 of the 34 items studied were suited for such mounting. However, study results could just as well apply to the five items that were found unsuited to standard rack mounting by assuming use of a special rack or bench with similar isolation. The microscope and some assessories are recommended for stowage. The results also could apply to stowage boxes, assuming that they are treated as any other equipment item.

3.2.2 Background Discussion

Spacelab Environment

Figure 3-1 defines the vibration environment assumed for the study. The data were taken from ERNO documents for equipment items weighing over 67 lb (30.0 kg) and mounted to Spacelab cylindrical area surfaces. The lower 3.3-g rms power spectral density (PSD) curve for random vibration and the sinusoidal levels were used in the SEEIR document and are the basis for modifying the rack-mounted equipment items for vibration. The 10-g rms PSD and sinusoid inputs were used to define the needed modifications for non-rack-mounted equipment items.

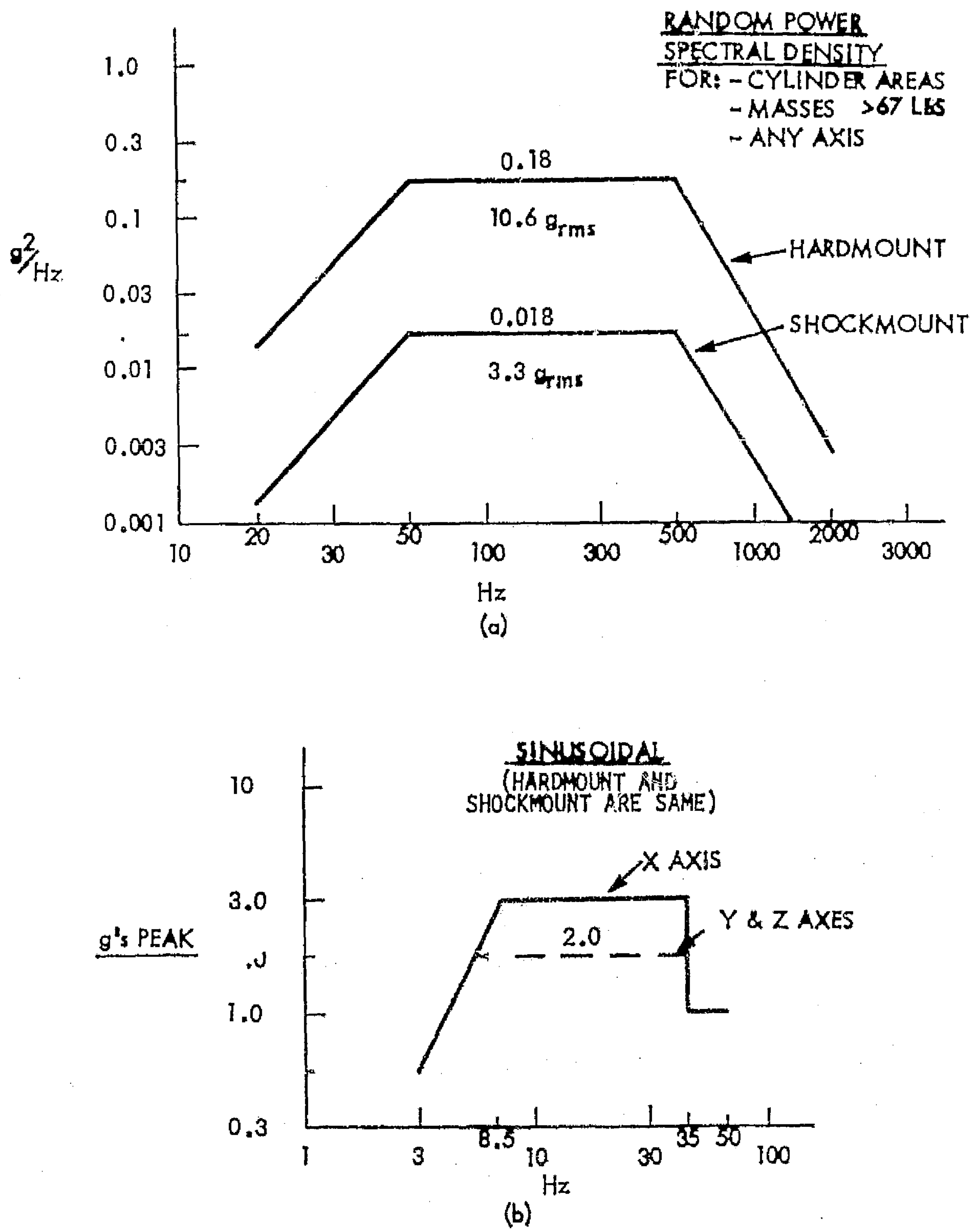


Figure 3-1. Spacelab Vibration Environment Used in Study

Equipment Item Capabilities

The CAM equipment items studied vary considerably in estimated vibration hardness. Many commercial items are designed without any specific vibration requirements outside of transportation and handling. Some items are relatively poorly built for any non-routine vibration. Others, such as the airborne and the Mil-Spec equipment, are more rugged. However, it is expected that minor fixes would be needed for even these units.

Only 11 of the 34 items reference a Mil specification capability or provide specific qualification levels. Most specifications are for maintaining in-specification performance when exposed to vibration, indicating that in general they could tolerate greater vibration levels when inoperative.

Figure 3-2 summarizes the vibration specifications published for 9 of the 34 selected equipment items. The curves show the maximum and minimum envelope of vibration qualification. Again, most data are for operating equipment. The maximum envelope limit is from avionics-type equipment. The minimum limit primarily comes from Mil specifications for sea-going vessel installations. The curve between the envelope limits indicates where most equipment item specifications cluster. Capability beyond 55 Hertz is generally not specified.

Superimposed on Figure 3-2 is the sinusoidal distribution curve of Figure 3-1(b). This is shown to underscore the conclusion that, ignoring the random inputs, verification of the low-frequency vibration capability is important. This is because an equipment item with low frequency resonances and transmissibilities of 10 or more (e.g., heavy components mounted on relatively large and flexible flat plates) could develop serious internal g loads on individual components.

It is evident that most equipment items will require a vibration survey to verify capability and identify any needed fixes. Alternatively, better isolation from Spacelab than that used in the study could reduce both the tests and the fixes needed.

Modification Costs

An evaluation of equipment modification costs indicates that 60 to 80 percent of the identified costs were due to vibration fixes. The percentages cannot be determined precisely because some vibration fixes also corrected other inadequacies, such as support for acceleration loads. The few items that required no vibration modifications fell into two categories: those with adequate ruggedness specified (i.e., RHG and Collins avionics communications gear) and those to be stowed (i.e., microscope and various assessories). It appears certain that more than half of the total modification costs could be saved, along with management and schedule gains, if increased isolation could be obtained.

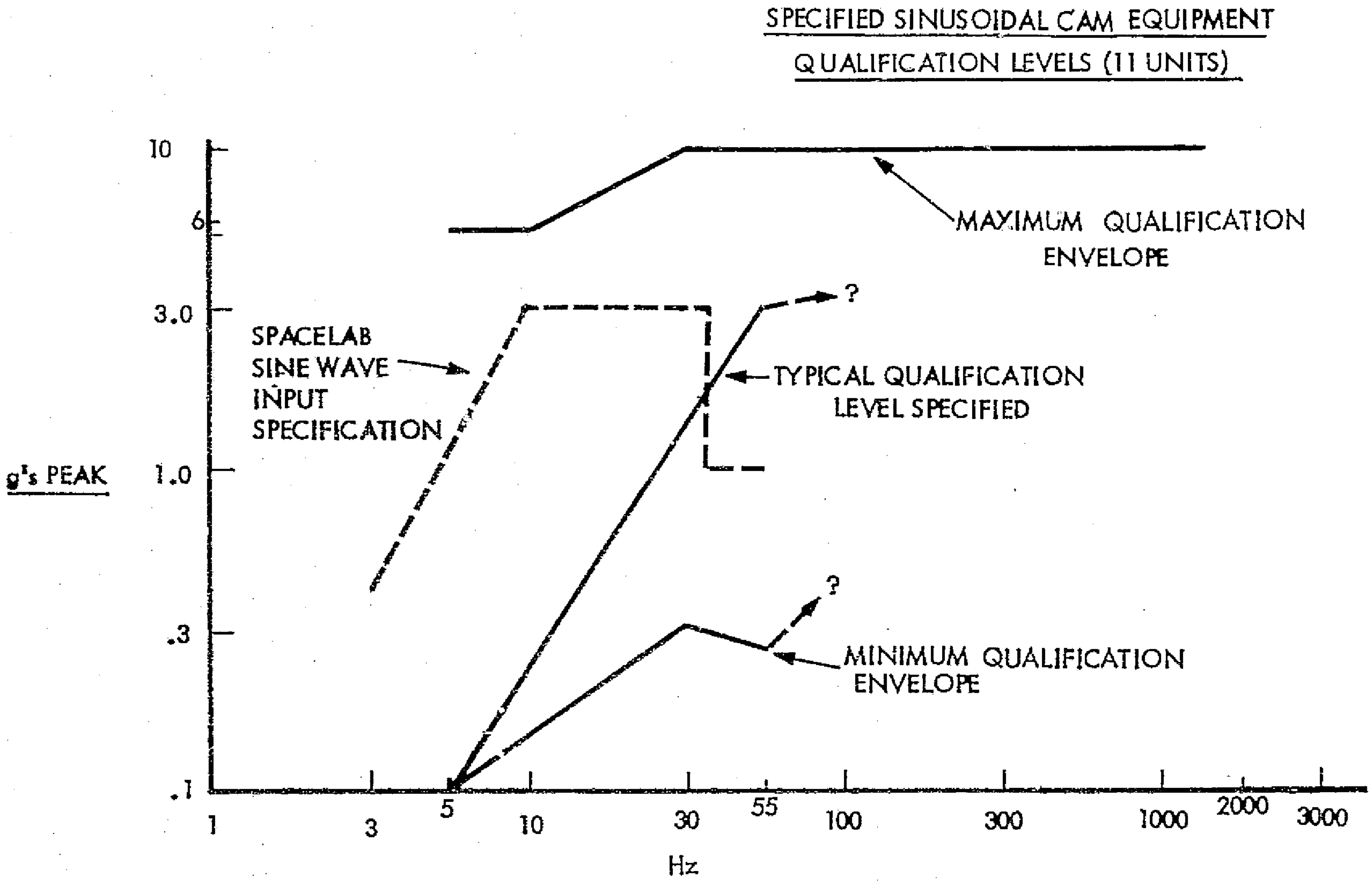


Figure 3-2. Envelope of Specified Capability for Equipment Items

3.2.3 General Considerations

There are two basic methods of isolating components--passive and active. Passive techniques are highly developed and inexpensive for simple applications that do not have critical interfaces or low-frequency problems. Active isolation is used to solve problems outside the inherent capability of passive isolators and is relatively expensive because of the use of servo control system components.

Passive isolators, due to their dampened spring characteristics, resonate an isolated system at a frequency which the equipment can withstand. The frequency is dependent upon the isolator spring constant and system mass. The frequency is usually chosen between 15 and 30 Hertz. The transmissibility at resonance varies from 1, with critical damping, to theoretically infinity at zero damping. The transmissibility decreases above resonance, becoming 1 at 1.414 times resonant frequency. The higher the transmissibility at resonance, the greater the attenuation as the frequency increases above resonance. There is no attenuation for frequencies lower than resonance.

The peak-to-peak displacement swing of the isolated component increases as resonance frequency decreases, and this becomes a key limiting factor in isolator capability. At 30 Hertz the maximum deflection is 0.01 inch (0.254 mm) per g (static deflection) on the isolated mass, or 0.01 inch (0.0254 mm) per input-g times transmissibility. At 15 Hertz the deflection is about 4 times that at 30 Hertz. At 5 Hertz the deflection is 10 times that at 15 Hertz.

As an example, an isolated system resonating at 5 Hz and with damping at one half of critical damping has a transmissibility of about 1.5 at resonance and static deflection of 0.4 in. (1.01 cm). With a 1-g peak input at 5 Hz (per Figure 3-2), the mass would deflect about $\pm$0.6 in. (1.5 cm). This can pose an isolator design problem to maintain linear characteristics over this swing and problems can arise with interfacing to the isolated mass. The effect of steady-state acceleration will be a problem. It should be noted, however, that at 30 Hz the transmissibility is down to $\leq$0.2, and down to 0.1 at 50 Hz. Attenuation begins at 7 Hz, where Figure 3-2 shows that the input reaches 2 g. A lower resonant frequency at 3 Hz would start attenuating at 4.2 Hz ($<$1-g input) and deflect about 1.5 in. (3.8 cm). The random PSD spectrum inputs would also be eliminated by either design.

It is evident that low-frequency attenuation is required if inputs to equipment items are to be reduced to levels that reduce modifications and testing significantly, unless equipment capability can be shown better than quoted specifications. The random input spectrum is effectively attenuated with low-frequency isolation but the sine wave spectrum is still of concern at the lower frequency end. Because of this, early verification of the sine wave spectrum characteristic is needed.

3.2.4 Alternatives

There are many possible system solutions to isolate the equipment items. Table 3-3 identifies the basic choices. Isolation systems within isolation systems or flexible systems are not covered.

Table 3-3. Basic Isolation Choices

Isolator System Level	Passive	Active
Units	Possible	Clearly not cost effective
Console	Possible	Probably not cost effective
Multi-Console	Possible	Probably cost effective
Spacelab	Possible	Likely cost effective

Active isolation is not cost effective for the smaller equipment clusters. It may be cost effective for a number of consoles mounted in one rigid system or at the total Spacelab level since the costs of all equipment would be reduced.

Low-frequency passive isolators may be feasible at the unit, rack or group-of-racks levels. They would be less desirable at the total Spacelab level because of the resultant interface complexities from large peak displacements. The assessments made were, therefore, aimed at the potential of passive isolation of (1) equipment units in hard-mount racks, (2) hard-mount units in passive isolated racks, and (3) hard-mount units in racks that are hard-mounted in groups to a passively isolated framework.

3.2.5 Comparison of Alternatives

Isolated Equipment Units in Hard-Mounted Racks

The major cost impact of isolating individual equipment items lies in (1) the development and procurement of the isolators, (2) design of the rack to accommodate the isolators and the combined motions and displacements of the equipment items, and (3) the lost volume needed to provide room for peak displacements.

The total cost recently incurred to oversee redesign, test, qualification and procurement of a typical vibration isolator for a spacecraft equipment item was about $75,000. The isolator and equipment unit mass resonated in the typical 15 to 30 Hertz region. It is estimated that lower frequency isolators would cost at least $150,000. The cost is relatively independent of the equipment item mass supported, but each item with significantly different mass or mass distribution would likely need separately developed isolators. Therefore, a direct cost of about $150,000 per unit could be expected to be incurred. This is far more than the estimated modification costs to upgrade the units for the Spacelab environments of Figure 3-1, which are generally less than $15,000.

The rack design would require modification to provide cooling air containment and to provide mountings for standard 19-inch rack-mounted equipment. A space within each rack of at least 1-1/2 inches (3.8 cm) would be needed to accommodate the peak-to-peak random phased displacements of adjacent equipment items. This space would reduce the number of 10-inch (25.4 cm) packages installed in a typical 8-foot (2.44 m) rack from 9 to 8. The rocking motions due to 3-axis excitations and mass unbalance may require even greater separation than the idealized single-degree-of-freedom calculations presented above.

Finally, inter-unit connections, mainly electrical cabling, would be impacted to such a degree that freedom to move without excess stresses or effects on isolation characteristics would have to be provided. It is concluded that it would not be cost effective or physically effective to attempt to isolate individual equipment units to filter out the low-frequency sine wave input of Figure 3-1(b).

Isolated Racks

Isolation of a rack will incur a cost for development and procurement of vibration isolators. Interface connections between the racks and Spacelab will be impacted and schedule flexibility may be reduced. Volume usage efficiency is much better than for the individual unit isolation case.

The isolator costs could be expected to remain about the same as for the equipment unit isolation case. However, a double bay rack 8 ft (2.44 m) high, holds 18 typical 10-inch (25.4 cm) high equipment units. The shared isolator cost per unit would then be less than $9,000 per unit, which is competitive with the average cost to modify the equipment. Several racks could perhaps use the same isolator design, provided that loaded weight characteristics could be made to fall within acceptable limits. This possibility requires further study.

The interface design problem between equipment units is eliminated by isolation of an entire rack, but the larger cable bundles between racks and Spacelab would require special design. Cooling air ducting or water lines going from the rack would require flexible connectors.

Some volume efficiency is lost due to rack-to-rack-to-Spacelab clearances. However, two more packages could be accommodated by the double bay rack as compared to the individual isolated unit approach.

The most serious potential problem is that total weight characteristic variations may require custom isolators for each rack. The flexibility of using Spacelab would be affected. Either the isolators could not be designed until the rack was loaded, or extensive precoordination and management would be needed to assign equipment items to racks and establish weight goals. Neither is compatible with a flexible user policy. This problem would be solved if a standard range of isolator designs were made available to accommodate various weight ranges. This issue requires an in-depth study to verify design feasibility and to establish the required design parameters.

In summary, the rack-isolated concept appears to have merit if a standard isolator selection concept can be developed to retain Spacelab schedule flexibility with minimum management efforts. An in-depth study is needed to determine feasibility and the design criteria for standard isolators.

Multi-Rack Isolation

The cost of isolators per equipment unit could be further reduced by increasing the number of bays per isolated system. A standard one- or two-bay

console (rack) concept could be retained by providing an isolated framework on which to mount several racks. Special bench configurations also could be accommodated and thereby eliminate individual equipment unit isolators where standard rack mount is not suitable.

If the full length of each side of each module in a Spacelab contained an isolated framework on which to mount standard racks, each could accommodate racks containing up to 45 typical equipment items. The cost for isolation would drop to less than $4000 per typical equipment unit.

Alternatively, approximately $450,000 per multi-rack system could be allocated to the development and production of an active isolator system and be competitive with individual equipment item modification. Assuming that the development could be shared among characteristically similar systems (2 per module or 6 per three-module Spacelab) the prorated costs could become relatively small.

Interface problems due to displacement between racks, as compared to individual rack isolation, would be eliminated. Interfacing with the Spacelab would not be any more difficult than with single racks since the Spacelab framework would be required to carry less rack-to-rack connections.

The impact on scheduling and management would be similar to that for rack-level isolation. If custom isolators were required for given loaded multi-rack assembly configurations, the ensuing difficulties probably would outweigh the cost savings to reduce equipment item modifications.

If, however, adjustable isolators or a sufficient range of isolator selections were available to accommodate the necessary weight distribution ranges, such an approach appears desirable. In-depth studies to define the mass parameters to be accommodate, evaluate technical feasibilities, and select the best design solutions are needed in order to pursue this course.

3.2.6 Conclusions

The following conclusions were made during the tradeoff study:

1. Grouping of equipment items into multiple-rack isolated systems would be cost-effective provided that the proper isolators are made available for the spectrum of weights and mass distributions. Detailed study is needed to define the problem and select the technical approach. Isolation of individual equipment items within racks is, as a general rule, impractical and not cost-effective.

2. A test program should be undertaken to understand the true non-operating vibration environment capability of CAM equipment. Two thirds of those studied were not tested to a defined vibration spectrum. Data for the other one-third quoted mostly sea-going vessel specifications for operating

conditions and many are capable of more stringent low-frequency inputs. Based upon visual examination, most items appear to require modifications to meet the December 1973 ERNO-specified Spacelab environments. The cost of these modifications represent over one half of the total modification costs identified.

3.3 MATERIAL CONTROL TRADEOFF

The objective of this trade study is to (1) determine whether it is feasible to reduce the Spacelab internal experiment equipment material control requirements from the level defined by the NASA equipment specification (EC006M00000A) to the study SEEIR specification, and (2) determine whether it is feasible to eliminate all material control requirements (except for mercury, cadmium and zinc).

The first objective was evaluated by a risk analysis which considered the cost differential between imposing the study SEEIR specification requirements and the NASA specification requirements upon the equipment, compared to the cost of modifying and reflying experiments which failed because of a material control type of problem.

The second objective was evaluated by comparing the cost savings expected by further relaxing the study specification material control requirements, with the costs of adding an active method of cleaning the Spacelab environment of increased outgassing products or isolating the increased outgassing products.

3.3.1 Relax Material Control Requirements from the NASA Specification to the Study Specification

The first question to be answered (if material control requirements are relaxed) is whether or not the safety of the Spacelab crew will be endangered in any way. After careful study, it was concluded that safety of the crew would not be compromised, based on the following rationale.

1. The 150-hour bakeout requirement will drive off an appreciable amount of the total outgassing products available from each equipment item.
2. Conformal coating of circuit boards will effectively reduce the total amounts of outgassing products coming from circuit board components.
3. Forced-air cooling of all rack-mounted equipment, and bench-mounted equipment which requires appreciable heat dissipation, will effectively cool all wire bundles and other sources of high heat generation. The danger of overheating is very remote.
4. Current design practices incorporating low-voltage circuits and fused high-power circuits indicate a very low probability of failure. Use of TFE insulation instead of PVC insulation reduces the fire hazard significantly.
5. If a fire should start in any equipment with forced air cooling, its ability to propagate is quite limited. The fan would be shut off and the fire would be self-extinguishing.

The absence of convection currents in zero-gravity, plus the absence of forced air over the equipment, would keep oxygen away from the equipment and therefore extinguish the fire quickly. Non-catastrophic and non-propagating failures are permitted in the NASA specification (EC006M00000A) when compatible with individual equipment reliability goals.

6. Those units that are sealed will not permit outgassing products to enter the Spacelab environment. No harm can come to the crew from this source.

7. Most hermetically sealed components are back-filled with an inert gas, so the flammability danger is extremely low from these units.

8. If an equipment failure should occur which would endanger the crew, what safety features are inherent in the Spacelab? Where can the crew go? First of all, the Orbiter will have face masks (with 30-minute oxygen tanks) and fire extinguishers available for immediate action against fire and smoke. The design of the Orbiter vehicle includes an airlock between the crew compartment and the Spacelab. The hatch on the crew compartment side will remain closed during experiment operations, with the hatch on the Spacelab side remaining open. If an equipment failure should occur which would endanger the crew, their last resort is to evacuate the Spacelab through the airlock. Once safely inside the airlock, the Orbiter flight crew would have the option of dumping the Spacelab atmosphere to space, thereby extinguishing any fire which might persist to the point of endangering the Orbiter vehicle itself.

A risk analysis was used to evaluate the cost effectiveness of relaxing the material control requirements down to the level of the study equipment specification. Relaxation of a specification increases the risk of equipment failure. The cost of incurring this risk was estimated to determine if relaxation of material control requirements is a cost-effective specification change.

This analysis of risk is based on (1) the statistical probability of equipment failure because the relaxed specification did not correct an equipment deficiency, (2) the cost to the experiment program if one or more packages fail during the program must be reflown, and (3) the cost differential between the NASA and the study level of material control requirements.

The results of the risk analysis are shown in Figure 3-3. The horizontal line represents the cost differential between the NASA and the study level of material control requirements. This line represents the additional cost of identifying all materials in the equipment, approving the listed materials and replacing any wire runs (internal to sealed units) from PVC to Teflon insulated wire. Since the cost is not probalistic, because it would be expended for all items of equipment, it is represented as a horizontal line.

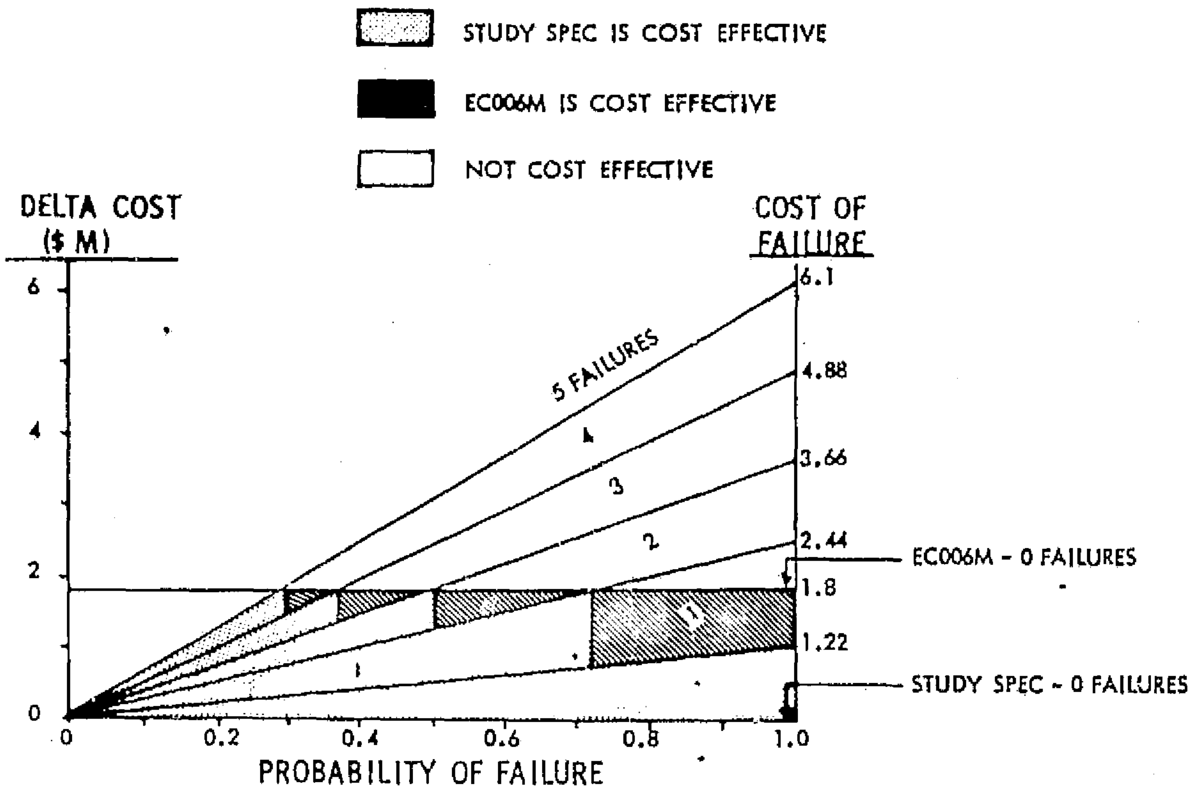


Figure 3-3. Risk Analysis for Relaxing Material Control Requirements from NASA Spec to Study Spec

The slanted lines represent the expectation of incurring the cost of modifying up to five units that failed due to a material failure. Since such a failure is probabilistic, the expected cost varies with the probability of occurrence. For example, the probability of five equipment failures occurring during the program may be only 1 in 10. Therefore, the expectation is only about $700 thousand. Another way of explaining this cost is that with a probability of 1 in 10, the total cost of five failures would only be incurred once in ten experiment programs. Therefore, one-tenth the cost of these five failures is apportioned to one experiment program.

The cost of a failure is based upon the cost to refly the failed experiment hardware and the cost to fix that hardware prior to reflight. Ten experiments are assumed to fly on any Spacelab; therefore, one-tenth the cost of reflying the Spacelab is assessed against that experiment. The cost per flight used was $10.45 million (1974 dollars) which is an average cost for 439 flights.

The intersection of the slanted and horizontal line defines the probability of occurrence where the cost of imposing the EC006 specification equals the cost of relaxing the specification to the SEEIR requirements. If only one failure should occur, it is always cost effective to relax the specification. The probability of two failures occurring during the program has to exceed 0.72 to make imposition of the EC006 specification cost effective. The probability must be greater than 0.5 for three failures to occur to make the EC006 specification cost effective and so forth.

The differences between the two specifications are small and should not result in significantly different failure rates. The major cost difference results from different material reporting requirements. An increased risk exists only for enclosed units. The SEEIR allows materials to exist in these units which would not be allowed by the EC006 specification. In the opinion of the study team, the probability of a material failure causing an equipment failure is not significantly different for the two specifications. It is believed that the probability of two failures occurring as a result of the specification differences is much less than 0.72. The probabilities for additional failures are also much less than the cross-over points shown on the figure. Therefore, relaxation of the hC006 specification to material control requirements defined by the SEEIR specification is recommended.

3.3.2 Elimination of All Material Control Requirements

The problem of increased material outgassing during normal use, because of the elimination of all material control requirements, has been evaluated by comparing two basic costs: the cost savings to be expected by not imposing the material control requirements of the study specification, and the costs of providing an active system which would either clear the Spacelab environment of the increased outgassing products or isolate the increased outgassing products.

Spacelab Modifications

Two alternative modifications to the Spacelab could be made to accommodate the elimination of all material control requirements for experiment equipment. The first alternative is to place all equipment in an inert atmosphere that does not co-mingle with the Spacelab atmosphere. The second alternative adds a contaminant control assembly to the Spacelab environment control system (ECS) and fire extinguishers for fire control.

Description of Alternatives

Alternative 1 is illustrated in Figure 3-4. Nitrogen is circulated through the equipment in a sealed rack to provide cooling. Heat from the equipment is extracted by a gas/liquid heat exchanger that interfaces with the Spacelab coolant loop. This concept is similar to the rack equipment cooling concept envisioned for Spacelab, except it uses nitrogen rather than air.

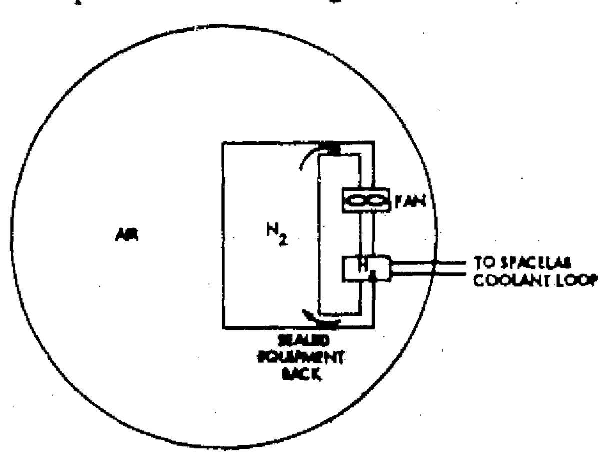


Figure 3-4. Isolation Technique for Rack-Sealed Equipment

Use of a separate, inert gas circulation concept eliminates the fire and toxicity hazards for rack-mounted equipment. Combustion cannot be supported in the absence of oxygen. Sealing of equipment racks prevents any toxics from evolving from the equipment into the breathable atmosphere. The pressure in the equipment rack can be maintained below that in the cabin to prevent any nitrogen leakage into the cabin by having a controlled leakage overboard.

The concept has many shortcomings requiring considerable analyses before adoption. Equipment sealing to prevent leakage of the nitrogen into the cabin would require extensive equipment modification. All openings require sealing. Access to the interior of equipment while in flight would be precluded. Bench-mounted equipment would require special provisions such as isolated compartments or enforcement of a materials control program.

A schematic of the ECS modifications required by Alternative 2 is shown in Figure 3-5. This contamination control approach is similar to that used in the Space Station Prototype System (SSP), developed by Hamilton Standard for NASA-JSC[1].

Trace contaminant concentrations are controlled by three principal means: (1) absorption on activated charcoal to remove most of the contaminants, (2) chemisorption by reactive solid materials to remove acidic and basic gases, and (3) catalytic oxidation to convert contaminants that are not otherwise controlled by the aforementioned concepts. Vehicle leakage also contributes to contaminant control, but because a specific leakage rate cannot be assured, a no-leakage condition is assumed.

The absorptive portion of the subassembly consists of activated charcoal beds. Charcoal is integrated with the lithium hydroxide canisters which absorb carbon dioxide.

Chemisorption occurs in two separate beds of reactive granular solids. In the first bed, ammonia is absorbed by copper-sulfated sorbeads (phosphoric acid impregnated charcoal is an alternative). In the other bed, various acid gases such as hydrogen chloride are absorbed by lithium carbonate. Addition of other materials to the lithium carbonate may be required for effective control of certain contaminants.

Contaminants not effectively controlled by the aforementioned techniques are eliminated by pyrolysis or oxidation in the catalytic oxidizer. The inlet air stream is heated to 600 F in a regenerative heat exchanger and then passed over a granular catalyst of palladium on alumina pellets. Contaminants are either decomposed or oxidized to carbon dioxide and/or water. An integral heater serves to maintain system temperature by compensating for heat losses. The outlet air stream is cooled in the regenerative heat exchanger before reentering the cabin atmosphere.

Fire extinguishers, not shown, consist of carbon dioxide fire extinguishers and full-face oxygen masks for the crew. CO_2 was chosen over other type fire extinguishers because it is easier to clean up, will not decompose to toxic products in the catalytic burner, will not damage the equipment, and its presence can easily be detected by man.

[1] Contaminant Removal Subsystem - Preliminary Design Package; SSP Documents 40, 41 and 42. Hamilton Standard, 1971.

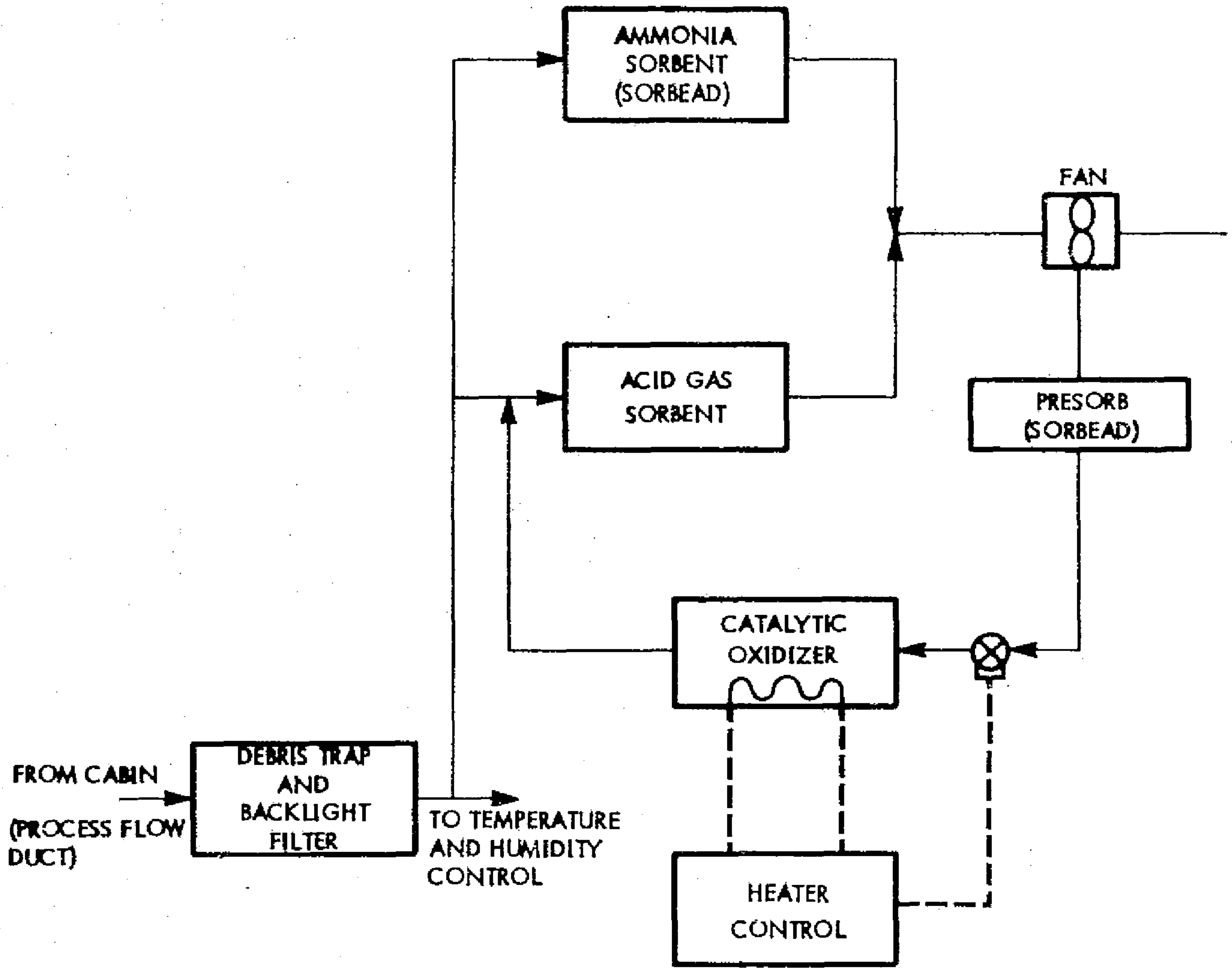


Figure 3-5. Contaminant Control Assembly--Trace Gas Removal

Comparison of Alternatives

Both alternatives are not cost-effective and were rejected. The inert gas isolation approach would cost at least as much as instituting a materials control program and would only be effective for the rack-mounted equipment. Sealing of rack-mounted hardware would require modifications as extensive as those required to meet the material control specifications identified in the Spacelab/Experiment Equipment Interface Requirements (SEEIR) document. Isolation of bench-mounted equipment requires special packaging and could affect equipment operations. Most likely, a materials control program would still be necessary for these packages. Institution of a materials control program for a portion of the equipment would not achieve the objective of further relaxation of material control requirements.

The contaminant removal subassembly and fire extinguisher approach also is not cost effective. Development of a catalytic burner and associated sorbent beds is estimated to cost \$5.7 million. Each unit installed in a Spacelab would cost an additional \$0.8 million. If three Spacelab modules are required for the sortie experiment program, a total cost of \$8.1 million would be incurred. The cost of fire extinguishers was not determined because they are supplied by the current Spacelab design. The \$8.1 million costs does not compare favorably with the estimated programmatic cost for modification of equipment to meet the requirements of the SEEIR specification, which is \$2.7 million. Therefore, this alternative is also rejected.

3.3.3 Conclusion

Reduction of material control requirements to a level defined by SEEIR is cost effective. A risk analysis showed that the expected costs incurred by a relaxed material controls specification are less than the cost of imposing the NASA equipment specification. The evaluation was based on the very low failure rate anticipated. No compromise to crew safety is envisioned by implementing the study material control requirements.

Further specification relaxation was evaluated by comparing the cost of implementing the study level of material control requirements versus the cost of nullifying the increased amount of offgassing products. It was found that the cost of removing the increased offgassing products by means of a catalytic burner (or the isolation of the offgassing products by cooling all rack-mounted equipment with a closed, gaseous nitrogen system) exceeded the cost of implementing the study material control requirements by a factor of 3. Crew safety could very well be jeopardized by the increased amount of offgassing products if special precautions were not exercised. Since these precautions were not found to be cost-effective, the recommendation is to implement the material control requirements found in the SEEIR specification.

3.4 MOISTURE AND FUNGUS AND CORROSION REQUIREMENTS TRADEOFF

The NASA specification for CAM equipment currently requires all materials used to be non-nutrient to fungus growth, or treated so the exposed surfaces will be fungus resistant. Also, the specification requires all metals to be corrosion resistant or to be processed to resist corrosion. Both of these requirements are intended to protect ground signal equipment from the deteriorating effects of climatic and service conditions encountered in military use.

The object of this trade study then is to determine if the requirements for moisture and fungus resistance, and corrosion resistance (as stated in NASA Specification EC006M00000A), can be waived without significantly reducing the life of the equipment.

3.4.1 Problem

The selection of materials for CAM equipment to be non-nutrient to fungus growth is difficult because fungus will thrive on almost any organic material where chemically unbound moisture is present. The growth of fungus can be detrimental to CAM equipment operation because, in time, the fungus may create unwanted grounding paths.

Also, the finishing of metallic surfaces to be placed in intimate contact with each other, by assembly, presents a special problem because intermetallic contact of dissimilar metals results in the formation of electrolytic couples when moisture is present. An electrolytic couple promotes corrosion through galvanic action. Corrosion degrades electrical contact between surfaces to the point where the equipment may fail to operate.

3.4.2 Discussion

The above definition of the problem is seen to depend on the amount of free moisture present. The more common types of fungi are known to thrive on moisture, either in the form of liquid water or ice crystals. The most widely documented example occurred during the latter years of World War II and a few years after its conclusion. Fungus thrived in gasoline storage tanks throughout the United States. The addition of lead caused the fungus to grow bigger, but the removal of all moisture caused the fungus to die out. The inference is that a controlled environment (where relative humidity is kept to low levels) will not promote the growth of fungus on CAM equipment.

In like manner, it is known that moisture promotes the formation of electrolytic couples. Experience has shown that relative humidities of less than 50 percent do not promote electrolytic couples when the metallic surfaces in intimate contact are reasonably protected. This experience was gained essentially on the Saturn S-II program and confirmed by ship and aircraft experience where relative humidity is controlled to a low level during long-term storage. The conclusion is that relative humidities maintained below 50 percent will not promote corrosion of metallic interfaces which are suitably protected by good commercial practice.

In order to substantiate the above mentioned experience of the NASA and Rockwell in the Saturn S-II program, discussions were held with Beckman and the Rockwell (Space Division) Instrumentation Laboratory. The discussion with Beckman Instruments confirmed that no special precautions against fungus or corrosion were incorporated in their commercial product line. Commercial practice does require that certain hospital items be protected against solvents and cleaning fluids. Generally, epoxy paints serve as the special finish for these applications. Epoxy paints have now become a common finish for most commercial instrumentation.

During the past two years, the commercial design guidelines have been revised considerably because of the Occupational Safety and Health Administration (OSHA) code which, in turn, calls out the National Electrical Manufacturers' Association (NEMA) code (electrical design features). The safety aspects include special grounding features, interlocks, labels, etc. To date, none of these guideline changes include fungus or corrosion protection.

The Rockwell Space Division Instrumentation Laboratory reported that the previous generation test equipment/instrumentation did have characteristic design problems (such as riveted ground lugs causing erratic ground returns), but the new equipment designs do not have any of these drawbacks. In fact, they report very few failures of the newer generation equipment--none being attributed to fungus or corrosion problems.

Rockwell is currently engaged in a NASA contract dealing with the ground operations associated with checkout and integration activities of flight-qualified experiments, from receipt through post-flight disposition (Spacelab User Implementation Assessment Study, NAS1-12933). Study requirements necessitate that the Spacelab be environmentally protected during all phases of experiment/instrument installation and integration as follows.

1. Installation of experiments/instruments will be accomplished at either an integration center (such as NASA-MSFC) or the user's facility. The user could be a NASA center, a university, or possibly a commercial source. The Spacelab will be located in a facility maintained at 50-percent (or less) relative humidity.

   In the case of modified commercial instrumentation, equipment drying could be accomplished at the supplier's facility, the instrument encased in a suitable plastic bag, dry nitrogen gas substituted for air in the bag, and the bag heat-sealed. This simple means of protection will assure a controlled relative humidity while the item is being transported from the supplier to the point of installation into the Spacelab.

2. The Spacelab will be transported from the point of experiment installation to the launch site by a Guppy-type aircraft. During this phase, it will be sealed and the controlled environment maintained inside the Spacelab.

3. At the launch site, the Spacelab will be serviced, checked out, and integrated with the Shuttle at the MSOB, MCF, and VAB, respectively. During all these operations, a 50-percent relative humidity (maximum) will be maintained.

4. When the Shuttle returns from a sortie mission, the Spacelab will be checked out and deserviced at the MCF and MSOB, respectively (launch site operations). A controlled environment will be maintained at each location.

5. The Spacelab will be transported back to the point of experiment installation by the Guppy-type aircraft, as described previously.

Also, recognizing that Spacelab flight operations are nominally 7 days in duration and occasionally last up to 30 days, during which time relative humidities up to 70 percent may prevail, this additional moisture could promote fungus growth and/or corrosion. When comparing this short time period with the succeeding six-month time period (average contract study time between flights for the same item of CAM equipment), we find there is more than adequate time for the controlled relative humidity (less than 50 percent) to dry out the moisture-ladened equipment during ground operations. Therefore, on the basis that the 70-percent relative humidity condition is not maintained continuously (a maximum condition only) and is applied for a relatively short time, the conclusion is that fungus growth and/or corrosion will not be promoted by this operating condition to the point of producing a failure.

The possibility always exists of an accidental spill of liquid during Spacelab flight operations, which could migrate to the CAM equipment and thereby promote fungus growth and/or corrosion. For this situation, four events would be necessary in succession: (1) the inadvertent spill of liquid, (2) the failure to notice the spill, (3) the failure to recontain the spilled liquid, and (4) the migration of the spilled liquid to the CAM equipment. If numerical probabilities were to be assinged to each event, and these probabilities multiplied together, it can readily be seen that the probability of all four events taking place in succession would be extremely small. So, rather than create an artificial probability number, it is preferred to say that the probability is so small that one can safety discount this event from happening within the Spacelab flight operating time span under consideration.

3.4.3 Stress Corrosion

Stress corrosion of metals in general depends upon a high level of prevailing stress--perhaps one half to three quarters of the yield strength of the materal--and the stress must endure over a considerable length of time. The stresses causing stress-corrosion failures are tensile, or have tensile components at the surface of the metal which must also be in contact with a corrosive environment. In most cases, temperatures considerably higher than room temperature must prevail in order to initiate and continue the process. Under these conditions, even very mild corrosive environments (such as atmospheric moisture) can eventually produce stress-corrosion cracking, provided the electrode potential relationships within the metal are fairly high.

Although many potentials may exist throughout the spectrum of instrumentation equipment under consideration where stress corrosion or intergranular corrosion could become a failure mechanism, the probability of such a failure mechanism existing is extremely low. The benign environment, which will prevail during all Spacelab ground operations, indicates that the conditions which would normally promote such a failure mechanism (corrosive environment and much higher than room temperatures) will be adequately controlled. In addition, the laboratory experience of Beckman Instruments, Hewlett-Packard, and Rockwell Autonetics Division has shown that there are no recorded failures from this failure mechanism.

As a precautionary measure, however, it is recommended that all pressure vessels be carefully examined for conditions (stress levels, fluids contained, expected maximum temperatures, etc.) which could promote stress corrosion. Corrective action should be initiated to alleviate any unfavorable situation.

3.4.4 Conclusions and Recommendations

Based on the data obtained and discussed above, the conclusion is that the CAM equipment will always be in a benign environment, and for this reason will not benefit from the more stringent choice of materials and finishes called for in NASA Specification EC006M00000A. The recommendation, therefore, is to waive the requirements for moisture and fungus resistant materials, as well as corrosion resistant materials, and to permit current good commercial practices to provide the degree of protection desired for CAM equipment.

The above conclusions and recommendations stem from the following data.

1. Relative humidities below 50 percent will not promote fungus growth nor electrolytic couples.
2. Beckman Instruments and the Rockwell (Space Division) Instrumentation Laboratory have not attributed any equipment malfunction or failure to fungus or corrosion problems stemming from climatic conditions.
3. Ground operations for Spacelab, being studied for the NASA under Contract NAS1-12933, implment a study ground rule requiring a 50-percent relative humidity (or less) environment for all Spacelab ground operations, including experiments.
4. The current OSHA code, including the NEMA code, has not addressed any special materials for moisture and fungus resistance or corrosion resistance.
5. An accidental liquid spill during flight operations is very remote.
6. Periodic flight operations at 70-percent relative humidity (maximum) are not of sufficient duration to promote fungus growth and/or corrosion.
7. The risk of sustaining a fungus or corrosion failure in flight is extremely small.

3.5 POWER DISTRIBUTION FOR EXPERIMENT EQUIPMENT STUDY

3.5.1 Introduction

The issue addressed by this tradeoff is whether it is more cost effective to modify experiment equipment items to utilize primary 28 vdc directly than to convert this power to 115 vac (60 and 400 Hz) and 220 vac (50 Hz) to be compatible with the equipment as currently designed.

Table 3-4 shows that most of the experiment equipment items analyzed require ac input power. These units generally contain internal power supplies converting input ac voltage to dc voltages regulated at various levels.

Conversion of the 28 vdc Spacelab primary power to various voltages and frequencies for input to these units (with subsequent reconversions to internal secondary voltages) represents a double conversion loss. Such conversion losses directly reduce the amount of available useful power, increase the heat rejection requirement for a given experiment load, and increase the weight of the conversion hardware. However, 28 vdc primary power may also not be a convenient power form, thereby also incurring conversion losses. This section compares the main elements of both power conversion systems in order to determine the relative electrical efficiencies, weights and costs involved.

3.5.2 Concept Descriptions

Existing AC Power Concept

Figure 3-6 diagrams the power conversion process assumed in the Spacelab for typical ac off-the-shelf equipment items. The Orbiter's 28 vdc is converted to ac by a dc-ac inverter comprised of a chopper and transformer with an ac filter to remove the strong harmonics induced by the chopper. The ac system may be 50, 60, or 400 Hz and one-phase or three-phase, but the diagram is representative of the basic processes involved. Several items may then be supplied by the ac power. Power conversion in each equipment item typically consists of an input transformer with several full-wave bridge rectifier-filters and electronic regulators to supply the required internal equipment voltages. There may be as many as six secondary power supplies supporting internal subassemblies. The regulators are typically series dissipation types, although chopper or pulse width-modulated types are also used.

The 28 vdc input is assumed to be regulated sufficiently so that distribution system voltage drops, load switching and fuel cell variations permit ±5-percent power at the equipment items requiring it. This function would likely be incorporated in the inverter design, but for convenience of this evaluation it is excluded.

Direct 28-VDC Concept

Figure 3-7 diagrams the dc distribution concept that eliminates the primary dc-ac inverter in Figure 3-6. The Spacelab dc input from the Orbiter has the same characteristics as the ac concept. These elements can be omitted from subsequent comparison discussions due to commonality.

Table 3-4. Input Power Requirements

ITEM	MANUFACTURER	VOLTAGE VALUE	VOLTAGE TOLERANCE (PERCENT)	NOMINAL FREQUENCY (Hz)	MAXIMUM POWER (WATTS)
VOLT/OHM METER	FLUKE	115*	±10	50/60/400	25
VOLT/OHM METER, MIL	FLUKE	115*	±10	50/60/400	3
TRANSCEIVER	COLLINS	26	±15	DC	200
MICROSCOPE	AMER OPTICAL	115	(±10)	60	(125)
DISPLAY TERMINAL	RESEARCH INC	117	±6	60	62
EMI METER	SINGER	115*	±9	50/60/400	30
ELECTROPHORESIS	BECKMAN	115*	±9	50/60	100
CHROMATOGRAPH	BECKMAN	117*	±9	50/60	250
LASER	SYLVANIA	115	(±5)	60	600
OSCILLOSCOPE	TEKTRONIX	113*	±20	50/60/400	60
OSCILLOSCOPE, MIL	H/P	115*	±10	50/60/400	125
NIM P/S	POWER DESIGNS	117*	±11	50/60	207
pH METER	BECKMAN	115*	(±5)	50/60	3
POWER SUPPLY	SORENSEN	115*	±9	50/60	1500
NIM PARTICLE COUNTER	ORTEC	117	±11	60	(100)
AMPLIFIER	NEFF	115*	±9	50/60/400	(500)/ 16 AMPS
STRIP CHART RECORDER	HONEYWELL	117*	±9	50/60/400	306
SPECTROPHOTOMETER	BECKMAN	115*	±13	50/60	230
SPECTRUM ANALYZER	H/P	117*	±8	50/60/400	285
FREQUENCY SYNTHESIZER	FLUKE	115*	±10	50/60/400	125
SPECTRUM ANALYZER	SINGER	117*	±15	50/60/400	50
MULTICHANNEL ANALYZER	NUCLEAR DATA	115*	(±5)	50/60	200
TAPE RECORDER	HONEYWELL	117*	±9	50/60/400	275/ 7 TRACK
TAPE RECORDER, AIRBORNE	AMPEX	26	±8	DC	175/ 14 TRACK
TIME CODE GENERATOR	DATATRON	117*	±10	50/60/400	35
NIM COUNTER-TIMER	TENNELEC	117*	±12	50/60	(175)
TRANSMITTER	RHG	113	(±10)	400	100
ELECTRIC FURNACE	ASTRO	220	±5	60	8000**
CENTRIFUGE	CLAY ADAMS	115	(±5)	60	205
COMPUTER	DEC	117*	±15	50/60	450

NOTE: VALUES IN PARENTHESES WERE BEST JUDGMENT IN THE ABSENCE OF SPECIFIC MANUFACTURERS' INFORMATION.

* ITEM CAN ALSO OPERATE ON 220V NOMINAL

** REQUIREMENT COULD BE REDUCED FOR LONGER WARMUP TIMES.

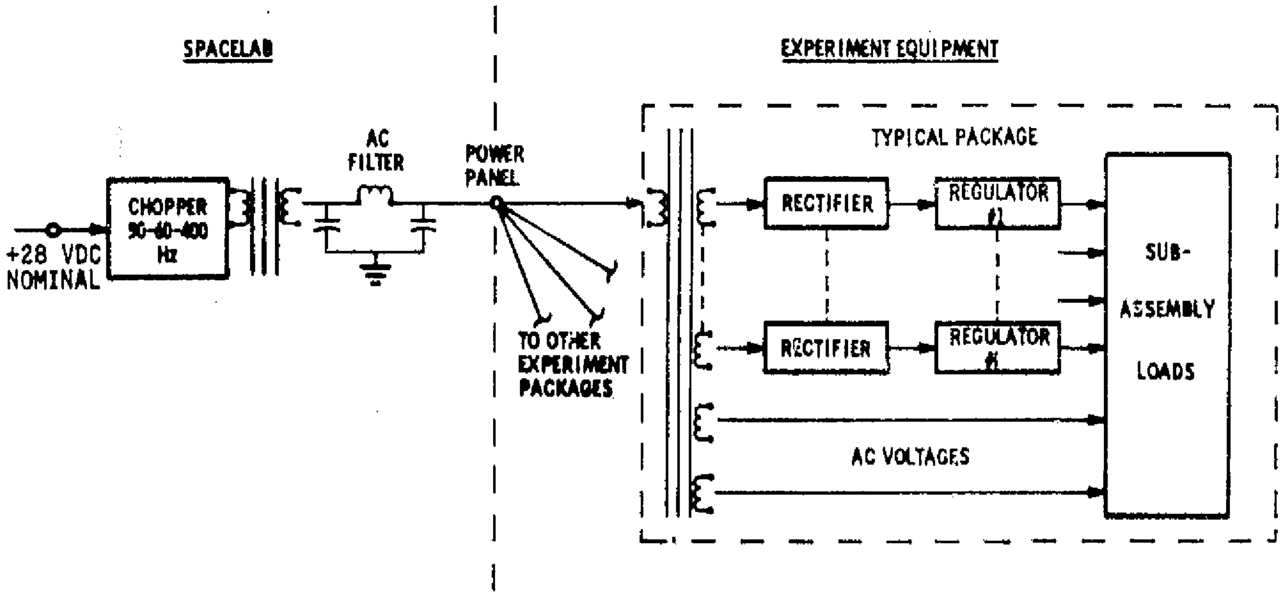


Figure 3-6. Assumed Power Conversion Diagram for Existing Spacelab Design

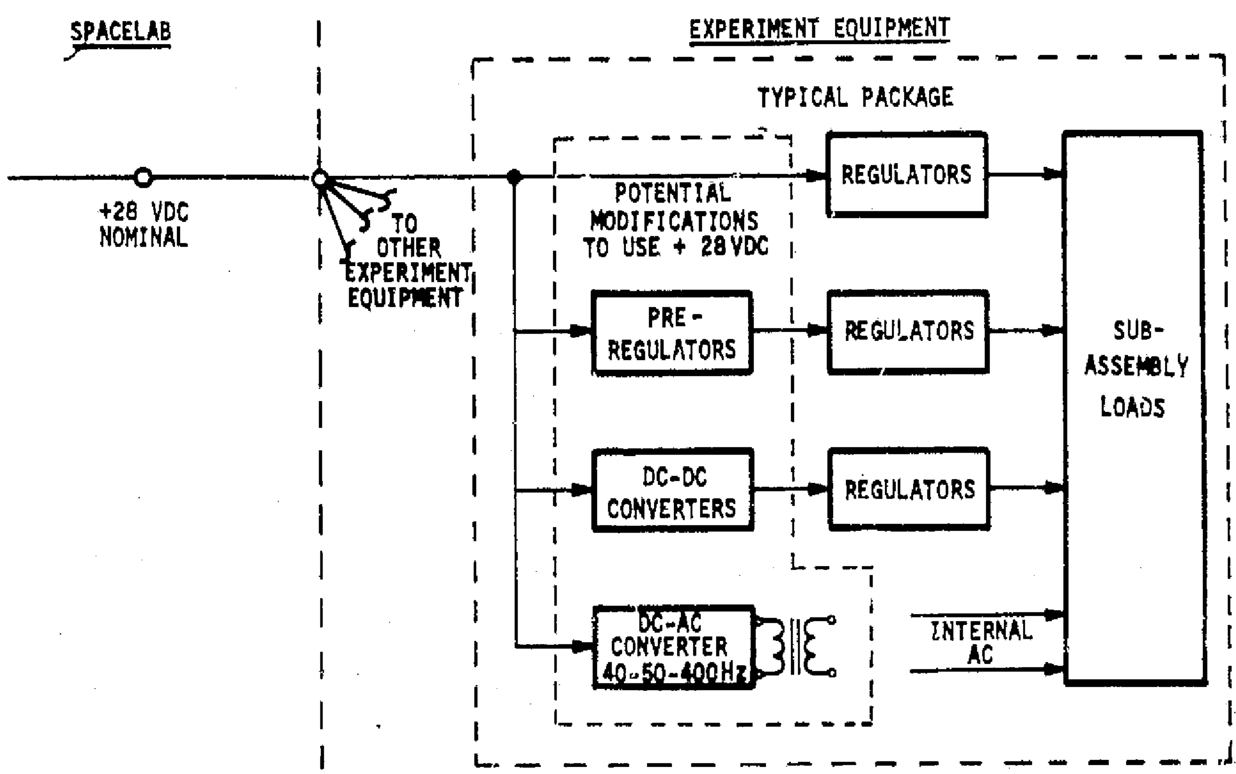


Figure 3-7. Power Conversion Diagram for 28 VDC Primary Power

Direct use of 28 vdc eliminates or modifies the input transformers and rectifier-filter circuits shown for the typical equipment item in Figure 3-6. Table 3-4 shows that almost all items studied use ac power and would be affected. Only two of the units evaluated are currently designed for 28 vdc operation. Figure 3-7 shows a number of potential conversion devices by which the equipment items may be able to utilize 28 vdc primary power. It is desirable to verify the dominant usage/conversion modes in order to identify the main power loss, weight and cost mechanisms, as well as to simplify the analysis. The discussion below considers these modes and comparisons.

Table 3-5 lists the various secondary voltage levels required by a 10-unit sample of the 34 units analyzed. The need for specific voltages and polarities, as well as power and regulation characteristics, varies with the package. Various combinations of up to six of the voltages shown may be found in a given package. Therefore, each package requires its own custom-designed power conversion.

Table 3-5. Secondary Power Supply Output Voltages of Selected Equipment Items

+5 vdc	+24 vdc
-5,	-24 vdc
+6 vdc	+40 vdc
-6 vdc	+100 vdc
+12 vdc	-100 vdc
-12 vdc	-200 vdc
-12.6 vdc	+248 vdc
+15 vdc	+400 vdc
-15 vdc	10 vac p-p
+18 vdc	1 vac p-p
+20 vdc	
-20 vdc	

Note: Currents range from negligible to several amps, and regulation varies from .05 to 20 percent.

Direct use of 28 vdc by equipment item subassemblies would be convenient. However, the units evaluated consume little 28 vdc directly. Direct input of +28 vdc power into secondary regulators would also simplify conversion circuitry. Unfortunately, only those regulators providing positive (+) outputs can potentially utilize +28 vdc as input. As Table 3-5 illustrates, as many negative as positive voltages are typically used. Supplies with negative output voltages require a dc-dc converter to establish the negative reference. In addition, voltage outputs higher than +28 vdc require a dc-dc converter to enable the voltage transformation.

Table 3-6 shows that direct 28 vdc input is efficient in only very limited situations, even where polarity and voltage magnitude constraints are met. Direct 28-volt input to the low voltage regulators will cause them to burn out. Use of dissipative pre-regulators to prevent burnout is very inefficient as

Table 3-6. Delta Dissipation to Operate Typical Regulators from 28 VDC

TYPICAL REGULATOR INPUT (V_i)	REGULATOR OUTPUT (V_o)	DELTA MULTIPLES	
		$\frac{P_D}{P_R}$	$\frac{P_D}{P_R + P_L}$
6.8	5	12.0	3.1
16	12	3.0	0.75
21	16	1.4	0.33
26	20	0.3	0.08
32	24	-	-

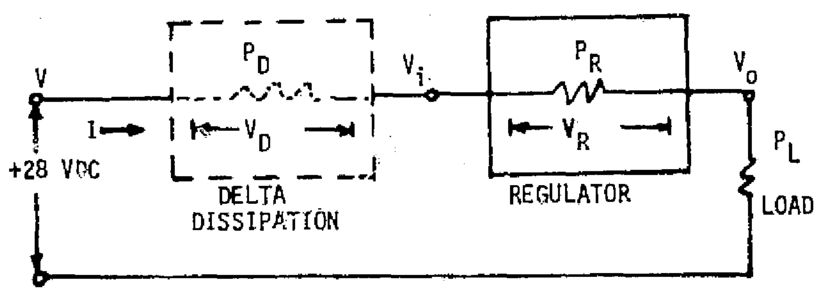
$$P_D = V_D I; \quad P_R = V_R I; \quad P_L = V_o I$$

$$\frac{P_D}{P_R} = \frac{V_D}{V_R} = \frac{V - V_i}{V_i - V_o}$$

$$\frac{P_D}{P_R + P_L} = \frac{V_D}{V_R + V_o} = \frac{V - V_i}{V_i}$$

P = AVERAGE POWER

V = AVERAGE VOLTAGE



can be seen by referring to Table 3-6, where typical values of regulator input voltage, V_i, are listed for several common regulator output voltages, V_o. A typical dissipative regulator drops V_i to V_o to dissipate average power, P_r. If average input voltage V_i exceeds the design value, then the increased voltage drop necessary to achieve V_o will cause additional power to be dissipated in the regulator circuit.

Alternatively, a pre-regulator could be inserted ahead of the regulator to dissipate the delta power, as shown in the circuit model inset in Table 3-6. The ratio of the power dissipated in the pre-regulator to the normal regulator power, P_D/P_R was calculated for each V_o, assuming that $V_i = 28$ vdc instead of the typical regulator input voltages. The table shows that the delta power dissipation is 0.3 of the normal regulator dissipation when V_o is 20 volts and that the delta power dissipation reaches 12 times normal regulator dissipation as V_o goes down to 5 volts. At best, a 20-volt output regulator may be able to accommodate a well-regulated 28 vdc input, while a 24-volt output regulator would operate satisfactorily with 28 vdc input.

The ratio of delta power dissipation to regulator-plus-load power,

$$\frac{P_D}{P_R + P_L}$$

was also calculated to determine the efficiency of using simple dissipative pre-regulators. As can be seen, from 8 percent to over 300 percent of the original required power could be dissipated in such pre-regulators. Since most solid-state circuits (particularly logic circuits) use 5 to 12 volts, the direct use of 28 vdc is very inefficient even where positive secondary voltages are needed. DC-to-dc converters are generally 85 percent efficient. Therefore, dc-to-dc converters would provide the most efficient means of converting most of the 28 vdc primary power to voltage levels useful for internal subassemblies in each equipment item.

Table 3-5 also indicates a need for internal ac voltages for units which use line frequencies for timing or clocking. With 28 vdc primary power, a dc-to-ac inverter with stable frequency control electronics is required to produce frequencies for such purposes. Still other units require ac power directly for motors, lamps or heaters.

From the above, it can be seen that nearly all power conversions from 28 vdc will involve dc-dc converters to provide optimum equipment item regulator inputs. Confirming this, the units in the study sample designed for 28 vdc input power utilize internal dc-dc conversion preceding low-voltage regulators.

Only a small part of the total power requirements are satisfied by direct use of 28 VDC. Simple series pre-regulators can be efficiently used only where the required secondary voltage is positive and lower than +28 vdc, and where the voltage drop dissipation would be comparable to a dc-dc converter.

Other Concepts

Some other possible system concepts for power distribution were not covered. It would be possible to utilize several separate lower voltage fuel cell or battery primary sources, for instance, to obtain negative polarities and more efficient input voltages. However, these are rather extreme concept deviations. The most efficient use of power would be to custom design all items for direct use of one or more primary fuel cell outputs. The latter approach would almost certainly cause prohibitive increases in equipment cost and schedule, since complete circuit redesign would be required, making the units custom-built units.

3.5.3 Comparison of the AC and DC Concepts

Comparisons of the Figures 3-6 and 3-7 concepts were made for conversion efficiency, weight and cost. The evaluations are summarized below.

Efficiency

The rationale above establishes that, for the dc power distribution concept, dc-dc converters must be added to the experiment equipment units for most of the power they consume. Figure 3-8 further details the dc approach to show the key components of the typical dc-dc converter. The ac concept is also repeated to facilitate comparison of the two concepts. The primary 28 vdc regulators and the equipment item regulators and loads that are common to both approaches are omitted from the diagrams for simplicity.

Figure 3-8 illustrates that both concepts actually operate as dc-dc converters. The main difference is that the ac approach uses an extra transformer and harmonics filter. Also, the conversion frequency for the typical dc-dc converter is much higher in order to use low-cost parts and decrease weight.

The rectifier-filters in the units, while likely to be of different detailed designs than those in unmodified units (particularly the filters), have comparable efficiencies since a given commutation diode voltage drop is constant over the frequencies concerned. For example, with a 2-volt rectifier drop the loss would be 10 percent for a 20-volt rectifier output; for a 6-volt rectifier output, the loss would be 33.3 percent.

Typical ranges of power losses for the different key components used in the two approaches are noted in Figure 3-8. Without detailed designs, a clear-cut efficiency advantage cannot be shown for either approach, but some advantage is indicated for the ac approach.

DC-to-ac inverters with filters in the kw range typically operate with a loss of 10 to 15 percent. An Apollo inverter unit had a loss of 15 percent, for instance. Small dc-dc converters exhibit greater losses primarily due to the greater proportion of power required by chopper and regulation electronics. However, the transformer losses in the units for the ac concept will offset the better inverter efficiency, making overall efficiencies of the two concepts comparable.

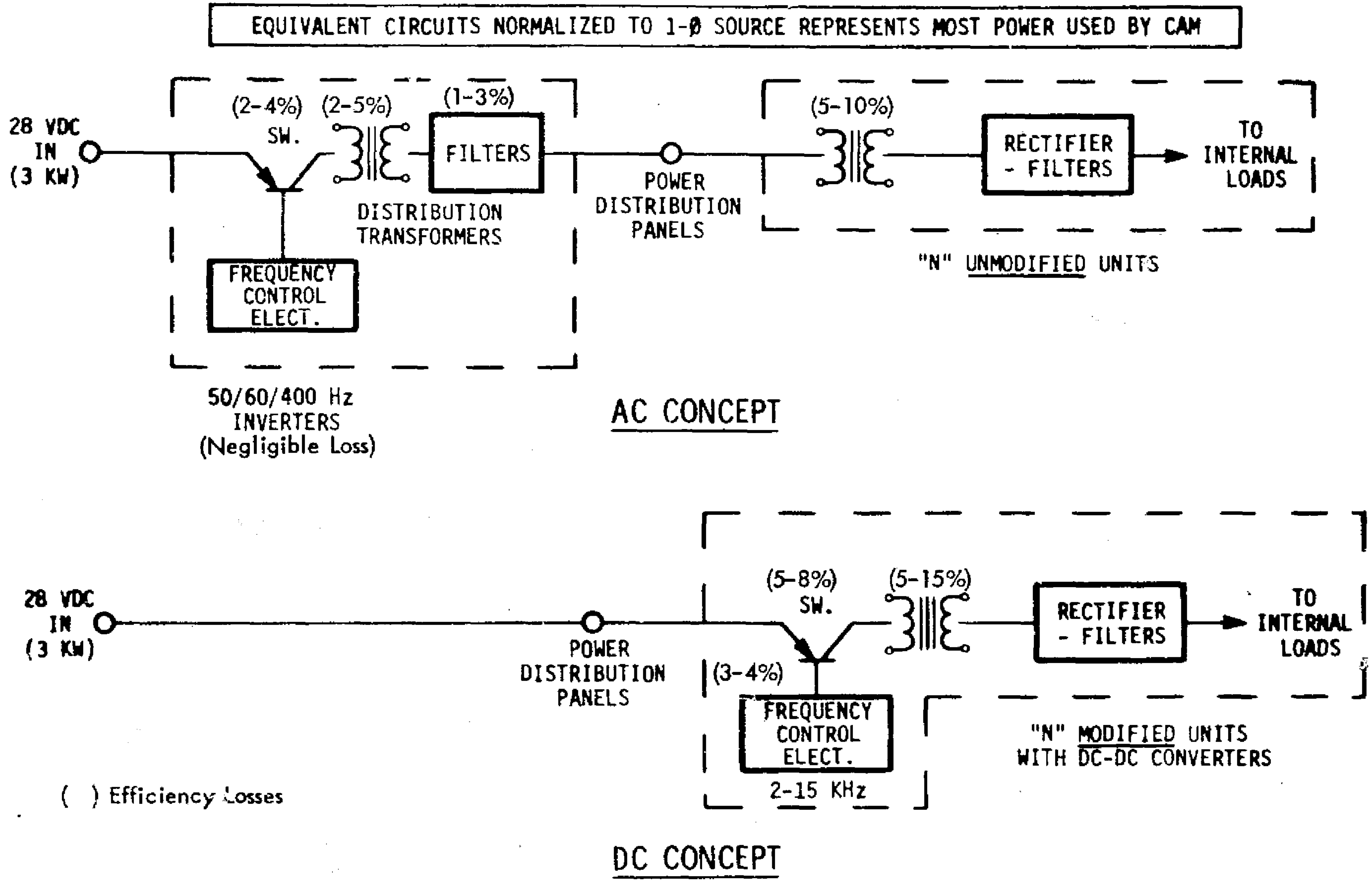


Figure 3-8. Equivalent Circuits for Power Distribution Alternatives

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Rockwell International

The available space in a package, left by the removal of its power supply, will probably not be adequate to accommodate efficient transformers in the dc-dc converter. The transformers used in the dc-dc converter concept would probably be less efficient than unit transformers in the ac concept.

The harmonic filter in the ac approach is a function of desired power sine-wave purity. High harmonic content left on the line will cause additional transformer or motor core losses in the units due to the higher losses that occur at higher frequencies. Increased EMI may also result without adequate filters. Generally, a fairly clean waveform is desired. This additional loss for the ac approach is likely to be offset by the higher chopper losses in the dc approach.

In summary, overlapping of loss ranges prevents a clear indication of the most efficient approach, but any difference is apt to be small.

Weight

The delta weight between the two approaches is comprised of differences in component weights and support hardware weights. Table 3-7 summarizes the weights of the main elements for each system.

Table 3-7 shows that the direct power system weight delta is primarily the difference between the dc-to-ac converter and filter in the ac approach versus the delta weight generated by modifying the units with dc-dc converters and the differences in weights for power distribution wiring.

A study by TRW on Space Vehicle Power Systems for Shuttle and Space Station (NNA 58-26270) used 13.5 lb (6.1 kg) per kilowatt for a 3-phase 400 Hz quasi-square wave inverter in over 1 kva sizes. Transformer weight (most of the converter weight) is stated to decrease according to increasing frequency to the 3/4 power. On this basis, converting 3 kw to 400 Hz power would require 41 lb (19 kg) plus 10 to 30 percent of transformer weight for filter weight. Conversion to 60 Hz would require 92 lb (41.8 kg) plus a correspondingly larger filter weight. Table 3-7 shows that about half the units can use 400 Hz power. Maximum use of 400 Hz power may be desirable to minimize weight. The less-efficient equipment item transformers are assumed to be 2/3 the weight of the 60 Hz line transformer. Units compatible with both 400 Hz and 60 Hz will not provide a weight savings typical of 400 Hz systems because their transformers are sized to operate on 60 Hz.

The weight of dc-dc converter modifications consists of transformers and electronics. The transformer weights were taken from the above-noted TRW study for 400 Hz operation. The electronic components were assumed to equal the transformer weights.

The weight for power distribution wiring can be expected to be heavier for the lower voltage dc system. If 3 kw is distributed as 115 vac, the distribution system must carry 26 amps. If 28 vdc is used, the distribution system

Table 3-7. Delta Weight Summary - Pounds (Kilograms)

Based on 3 kw Distribution; 2% Line Volt Drops; 100 ft, 2-Wire Systems

Concept	Electronics	Transformers		Distribution		Total Weight
		Units	Distribution	Filters	Wiring	
60 Hz ac	5	60 (27)	92 (42)	9-28 (4-13)	16 (7)	182-201 (83-91)
400 Hz ac	5	60 (27)	41 (19)	4-13 (2-6)	16 (7)	126-135 (57-61)
DC	29 (14)	29 (13)	--	--	256 (116)	314 (143)

NOTE: Excludes primary regulators, structures for support/heat sinks, and unit rectifiers/filters/regulators/loads (assumed equivalent for both concepts).

must carry 107 amps. For the same line loss, the I^2R loss of the dc system must equal the I^2R loss of the ac system, or

$$(26)^2 R_{ac} = (107)^2 R_{dc}, \text{ or } R_{dc} \simeq 0.06\ R_{ac}.$$

The percentage line voltage drops will now be the same for both systems.

If the equivalent of No. 6 AWG is assumed for the ac system in order to hold voltage drops to less than 2 percent over a 100 ft (30.5 m) equivalent two-wire system length, then the 28 vdc concept requires two 4/0 AWG size wires in parallel. The weight of No. 6 AWG is 16 lb (7.25 kg), and the weight of the doubled 4/0 AWG is 256 lb (115 kg). The wiring for the dc system, therefore, weighs 16 times more than that of the ac system based upon the same power losses.

The weight of support systems (reactants and heat rejection), incurred by the delta inefficiencies between the two approaches, can be discounted since the efficiency evaluation showed little difference between the two systems.

In summary, a significant weight savings is indicated with high-voltage ac power distribution as compared with low-voltage dc power distribution.

Cost

The ac power distribution approach requires no power supply modifications to the experiment units, but will require development of Spacelab power conversion equipment to provide the standard voltages and frequencies required by the experiments. This equipment consists of a 3-phase, 115/200 vac, 400 Hz inverter; a 115 vac, 60 Hz inverter; and a 220 vac, 50 Hz inverter.

The dc power distribution approach requires no Spacelab power conversion equipment for experiments (some will be required for Spacelab subsystem equipment), but will require extensive redesign and modification of almost all experiment units. Due to the large number of combinations of internal voltages and characteristics, and the variation in space available in the units, custom power converter designs will be required for each unit. Experiment ac power requirements will result in dc-ac inverters that can affect volume and, in some cases, thermal design. Although the parts costs of the chopper, transformer, rectifiers and filters for each small dc-dc converter is small compared with a large dc-ac inverter, the frequency control, overall design complexity and development costs are comparable. It can reasonably be expected that the requirements for experiment package power supply modifications (one for each package) will result in many times the cost of three dc-ac inverters used in the Spacelab ac power distribution.

Table 3-8 summarizes the comparative costs of the two Spacelab power distribution approaches. Estimated costs are based on 282 experiment package types identified in the functional data bank.

Table 3-8. Delta Cost Comparison of AC and DC Power Distribution

	CONVERSION UNIT	ESTIMATED DEV. COST EA. UNIT ($K) *	DEVELOPMENTS IN PROGRAM	ESTIMATED UNIT COST ($K)	NUMBER OF UNITS IN PROGRAM *	HARDWARE COST ($K)	PROGRAM TOTAL ($K)
AC POWER DISTRIBUTION	3-PHASE, 115/200 VAC, 400 HZ INVERTER: 2.2 KVA	100-150	1	6-7	3	20	145
	115 VAC, 60 HZ INVERTER: 1.0 KVA	75-100 } 150	1 } 1	5-6	3	17	92
	220 VAC, 50 HZ INVERTER: 2.0 KVA	75-100 } 150	} 1	5-6	3	17	92
	28 VDC, REGULATED $\pm 2\%$, DC-DC CONVERTER: 500 WATTS	50-70	1	4-5	3	14	74
	TOTAL						403
DC POWER DISTRIBUTION	DC-DC CONVERSION MOD, 1-3 OUTPUTS	50-70	} 285	2-3	788	1,970	10,430
	DC-DC CONVERSION MOD, 4-7 OUTPUTS	50-70	} 285	5-7	788	4,728	13,188
	TOTAL						23,618 + EXPERIMENT EQUIPMENT MODIFICATION COSTS

*BASED ON 3 SPACELABS, 282 UNIQUE EXPERIMENT ITEMS (1577 TOTAL) PER PROGRAM

3.5.4 Conclusions

It was concluded that there is no easy way to eliminate the double conversions that take place in both approaches, short of complete redesign of the equipment for optimum use of source power. This would mean completely redesigned custom units with the attendant cost impact.

The ac power distribution system is the lowest cost approach to accommodate the wide range of CAM equipment studied. The cost of many new dc-dc converter designs, unit modifications and attendant problems for the 28 vdc primary power distribution system far overshadows the cost of the standard inverters used in the ac distribution system. The ac system weight is indicated as approximately 150 lb (68 kg) less than the dc system. The greater dc power wiring weight more than offsets the ac inverter weight.

C - 6

4.0 EQUIPMENT QUANTITY EXTENSION

All analyses performed in the study thus far relate to specific equipment items. The extent of NASA's commitment to the use of CAM hardware must be based on programmatic impacts. This section describes the determination of the experiment equipment quantities estimated for the Spacelab during the entire sortie experiment program.

4.1 EXTENSION ANALYSIS

The approach employed to extend results obtained from the analysis of individual equipment items to the entire sortie experiment program is based on the assumption that hardware with similar physical characteristics will require approximately the same modifications. Briefly, results were extended by estimating the number of all equipment types identified for installation in the Spacelab, correlating each type with a related selected hardware type, and weighting the results obtained from the analysis of each item by its relative representation among all equipment types.

The quantity of each type of equipment is based upon the quantity of hardware identified for each payload and the number of sortie flights identified by the October 1973 issue of the 1973 NASA Payload Mission Model. Table 4-1 reproduces the sortie portion of this mission model. The number of equipment sets required by each payload is established by applying a five-year equipment life ground rule and a six-month minimum turnaround time for each experiment module. The rationale for these ground rules appears in Section 2.4.2.1 of Volume II. Table 4-2 shows the quantity of equipment sets resulting from the application of these criteria to the flight schedule of each discipline. The number of equipment sets could be reduced in some cases if the equipment life were increased one year (e.g., AST-10, PHY-7, ST-2 and C/N-3). Revision of the ground rule was not adopted since the Shuttle/Spacelab experiment program will probably extend beyond 1991, making good use of the hardware sets currently estimated to be needed during the last year of the mission model.

Table 4-3 shows the quantities expected for each type of equipment in each science and applications discipline in the sortie experiment program. In most cases, the quantities of a given equipment type identified for each discipline in the functional requirements data bank were multiplied by the number of equipment sets estimated for that discipline. Variations to the five-year replacement rule were made for those equipment types where technology changes have been slow, or where improved technology would not improve the scientific benefits obtained from Spacelab operations. For example, the microtome has been essentially the same since 1908, so it appears that a low probability exists that changeout to allow for improved technology will be needed. TV displays are another example of equipment that need not be changed to accommodate technology improvements. Improvement of a display terminal used to monitor deployment of a pallet-mounted antenna would not lead to

Table 4-1. Sortie Payload Summary (1980-1991)

Payload Code	Payload	Calendar Year 1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Total
AST-10	Stellar Astronomy		1	2	2	3	4	5	3	4	3	3	3	33
AST-11	Solar Astronomy	1	1	1	2	2	3	2	3	2	3	2	3	25
PHY-6	High-Energy Astrophysics	1	1	2	2	2	2	2	2	2	2	2	2	22
PHY-7	Atmospheric and Space Physics		1	1	1	3	3	4	3	4	3	4	3	30
EO-8	Weather Simulation Lab, Sensor R&D	2	2	2	2	2	2	2	2	2	2	2	2	24
EOP-10	Earth and Ocean Dynamics Experiments	2	2	2	2	2	2	2	2	2	2	2	2	24
SP-1	Crystal Growth, Biological Separation, Metallurgy	1	2	4	4	4	4	4	4	4	4	4	4	43
LS-2	Life Sciences Lab	2	2	2	2	2	2	2	2	3	3	3	3	28
ST-2	Advanced Technology and Chemistry Lab	2	4	4	4	4	4	4	4	4	4	4	4	46
C/N-3	Antenna Configurations, Laser Technology, Traffic Management Techniques, Energy Transfer Experiment		1	1	1	1	1	1	1	1	1	1	1	11

Table 4-2. Equipment Sets

PAYLOAD CODE	CALENDAR YEAR 1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	TOTAL
AST-10													5
AST-11													5
PHY-6													3
PHY-7													5
EO-8													3
EOP-10													3
SP-1													5
LS-2													4
ST-2													6
C/N-3													3
													42

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Table 4-3. Equipment-Type Representation

Item	Mission Model Identification: AST-10	AST-11	PHY-6	PHY-7	EO-8	EOP-10	SP-1	LS-2	ST-2	C/N-3	Total Quantity	Similar Selected Equipment	Remarks
Accelerometer								48	6		54	Amplifier	
Acoustical Generator					3				18		21	Power Supply	
Acoustic Transducer					72		5	8			85	Amplifier	
Bandpass Filter				10							10	Spectrum Analyzer	
Air Sample Unit								4	6		10	Strip Chart Recorder	
Audio/Stereo Headset								4			4	Amplifier	
Blood Cell Counter/Analyzer								8	6		14	Selected	
Blood Circulation Instruments								24			24	Computer Input/Output	Includes blood flow and pressure sensors
Refrigerator/Freezer							4	6	2		12	Selected	Reduced replacement rate--slow tech. changes
Metabolic Analyzer								4			4	Gas Chromatograph	
Directional Calorimeter							5				5	Oven	
Camera, Cine /				2	1	6	4	2	12	1	28	Buy Available	Reduced replacement rate; improved technology
Camera, Still				6	2			12	6	2	28	Buy Available	not significant to experiment results
Centrifuge, Standard/Refrigerated								4	2		6	Selected	Reduced replacement rate; slow technology change
Gas Chromatograph/Gas Analyzer							25	12	18		55	Selected	
Bacteria Colony Counter								4			4	Particle Counter	Colony counters both automated and manual
Keyboard Terminal	5	5	3	5	3	3	5	4	6	3	42	Selected	
Digital Phase Meter									6	3	9	Volt Ohm Meter	
Computer	5	5	3	5	3	3	5	4	6	3	42	Selected	
Computer and Data Storage I/O Devices (amplifiers, A/D converters, etc.)	5	5	3	15	6	3	5	8	6	18	74	Selected	Quantity lower than expected
Symbol Generator	5	5	3	5							18	Computer Input/Output Device	
Scanner Programmer							5			9	14	Computer	
Disk Storage System								4			4	Tape Recorder; A/D Converters	
Dewar					3		5	4	6		18	Selected	
Bit Error Counter										3	3	Timer	
Dialysis Unit								4			4	Electrophoresis	
Physiological Monitor								4			4	Amplifier	Includes ECG, EMG, VCG, and EMG
Anthropometric Grid								2			2	Buy Available	Reduced quantity because of low technology change
Electrophoresis							5	4	5		14	Selected	
Ergometer/Dynameter								8			8	Centrifuge	
Microfilm Viewer	2	2	1	2	1						8	Strip Chart Recorder	One per module; no changeout
Flow Meter							5	4			9	pH Meter	
Spectrum/Wave/Multichannel Analyzers				40	3				6	9	58	Selected	
Signal Generator				10				4	6	6	26	Spectrum Analyzer	
Furnaces/Ovens							16	4			20	Selected	Quantity reduced; technology change low
Ultrasonic Cleaner								2			2	Dewar	Quantity reduced, technology unimportant
Hematocrit								4			4	Electrophoresis	
Dew Point Sensor					3			4			7	pH Meter	
Incubator							2	24	4		30	Furnace/Ovens	Quantity reduced; slow technology changes
Patch Panels				20							20	Amplifier	Quantity reduced; slow technology
Modem										12	12	A/D Converter	
Deonizer, H_2O								2			2	Electrophoresis	Quantity reduced; technology not significant
Laser Optics										15	15	Microscopes	
Lasers					3		20	4		12	39	Selected	

Figure 4-3. Equipment-Type Representation (Cont)

Item	Mission Model Identification										Total Quantity	Similar Selected Equipment	Remarks
	AST-10	AST-11	PHY-6	PHY-7	EO-8	EOP-10	SP-1	LS-2	ST-2	C/N-3			
Light Source									4		4	Buy Available	Quantity reduced; technology not significant
Lyophilization Unit							5		6		11	Refrigerator	
Magnet									2		2	Power Supply	
Microphone								2			2	Amplifier	Quantity reduced; technology not significant
Microscope					6			8	12		26	Selected	
Microtome								2			2	Selected	Quantity reduced; technology slow
Attenuator Calibrator										12	12	Spectrum Analyzer	Electronic equipment
Motor, Electric									2		2	Centrifuge	Quantity understated
Radiation Counter (active)							5	12			17	Selected	
Film Badges									48		48	Buy Available	
Radiation Sources								4	6		10	Buy Available	
Three-Axis Controller	2	2	1				2				7	No Correlation	Quantity reduced; technolgy change insignificant
Waste Compactor/Storage								4			4	Microtome	Mechanical
Optical particle detectors					3		10				13	Spectrophotometer	Photomultiplier tube, optics (No G-dependency)
Optical Sensor					48						48	Microscope	
Oscilloscope				5	6		5	4	6		26	Selected	
pH Meter							5	4			9	Selected	
Photoprocessor (holographic)							5				5	Laser	
Optiscan								4			4	Cameras	
Plethysmograph/Impedance Pneumograph								4			4	Amplifier	
Power Meter							5			6	11	Amplifiers	
Power Supply/Conditioners					12		16		4	2	34	Selected	Specific quantity reduced; technology change insignificant; total may be greater
Compressors/pumps					2		4	2	2		10	Centrifuge	Mechanical, rotary equipment
Tankage					8		8		30		46	Dewar	Quantity reduced; technology change insignificant
Temperature sensors					4			N	4		N	Amplifiers	
Pyrometer							20		6		26	Microscope	Small, easily stored
Tape Recorders	5	5	3	15	12	3	5	8	30	3	89	Selected	
Strip Chart Recorders/X-Y Plotters/Printers				30			5	8	6	9	58	Selected	
Specimen Containers								50			50	Buy Available	Quantity understated; technology change insignificant
Spectrometer/Spectrophotometer					3		15	12	30	6	66	Selected	
Receivers								28	6	48	82	Selected	
Transmitters				15	3					6	24	Selected	
Sterilizer								2			2	Oven	Quantity reduced; technology change slow
TV Display	2	2	1	2	1	1	2	2	6	1	20	Oscilloscope	Quantity reduced; changeout due to wearout, not technology
TV Camera					1		2	42	6	1	52	Buy Available	
Temperature Controller					1			4			5	Amplifier	
Timer	2	2	1	2	1	1	2	2	2	1	16	Selected	
Staining System								2			2	Buy Available	
Kits, Life Science								14			14	Buy Available	No duplication, assume carry-on equipment
Urine Analyzer								4			4	Electrophoresis	
Pressure Sensors								9	6		15	Amplifiers	
Valves					29		8				37	Microtome	Quantity reduced; changeout due to wearout, quantity understated
Power Divider										6	6	Amplifier	
Voltmeter							5	4	6	6	21	Selected	
Vacuum Cleaner									2		2	Centrifuge	
Clinostat									2		2	Centrifuge	

improved experiment results--only an improved picture of the antenna deployment. Since the benefit was not scientific, the change was not adopted. Instead, a quantity equal to the number of experiment modules estimated for that discipline was used.

The related, selected equipment items for each equipment type are also shown on Table 4-3. Relationships are primarily physical. In some cases the relationship may seem to be contrived. Such problems will always result when 90 different types of equipment are placed in 25 categories. However, the team attempted to minimize this problem during the equipment selection activity in selecting hardware representative of broad categories of equipment. Certain equipment types do not have related hardware identified; instead, an entry of "Buy Available" appears. These items could be obtained by either purchasing equipment that has been flown on previous spacecraft (such as TV and film cameras) or equipment that would not require any significant changes from its currently available state, such as radio-isotope elements. Since the available hardware can be flown essentially "as is," the same cost was entered in both the CAM hardware and the custom-built space hardware cost categories in the cost analysis presented in Section 7.0 of Volume II.

Table 4-4 shows the distribution of all equipment types categorized according to related, selected equipment types. Equipment acquisition is assumed to occur one year prior to the year the equipment is first scheduled to fly. The peaks and valleys reflect the five-year equipment replacement guideline.

Table 4-4. Related Equipment Quantities Projected for Experiment Program

Representative Equipment Types	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Total
Tape recorder	22	14	3	–	4	22	14	3	3	8	21	15	129
Computer	10	9	2	–	2	10	9	2	–	2	10	9	65
Keyboard/Display Terminal	23	8	2	–	4	2	–	–	4	1	–	–	44
Blood Cell Counter	3	1	–	–	–	3	1	–	2	–	3	1	14
Timer	12	22	1	–	2	6	5	–	1	–	6	4	59
Spectrophotometer	15	5	3	–	–	15	5	3	6	–	15	5	72
Receiver/Transceiver	15	14	–	–	–	15	14	–	14	–	15	14	101
Transmitter		6			2		6			2		6	22
Signal Conditioners	78	19	10		4	75	15	10	26	4	75	15	331
Spectrum/Wave Analyzers	6	21	–	–	13	7	19	–	1	13	7	21	110
Laser Assembly	7	5	5	–	–	7	3	5	–	–	7	3	42
Gas Chromatograph	12	3	5	–	–	11	2	3	4	–	12	2	54
Microscope	26	9	6	–	–	19	1	6	2	–	19	1	89
Strip Chart Recorder	11	12	1	–	6	5	10	1	2	4	6	11	69
Volt/Ohm Meter	9	8	1	–	–	9	8	1	1	–	9	8	54
Oscilloscope	16	10	2	–	4	8	4	1	2	2	7	4	60
Electrophoresis	5	1	–	–	–	3	1	–	4	–	3	1	18
Furnace/Oven	17	1	10	–	–	1	–	–	3	–	1	–	33
Dewar	5	1	1	–	–	4	1	1	3	–	4	1	21
Power Supply	28	8	11	–	–	7	–	–	–	–	7	–	61
Centrifuge	15	3	–	–	–	6	–	–	8	–	6	–	38
Refrigerator/Freezer	10	3	2	–	–	8	2	2	4	–	7	2	40
Particle Counter	6	–	1	–	6	–	3	3	–	6	–	–	25
Microtome	3	–	–	–	–	–	–	–	3	–			6
pH Meter	6	–	3	–	–	6	–	2	3	–	4	–	22
Total	360	183	69	–	47	249	123	43	96	42	244	123	1579